TO THE

REV. WILLIAM VERNON HARCOURT,

F.R.S., F.G.S.

WHO AS FIRST PRESIDENT OF THE YORKSHIRE PHILOSOPHICAL SOCIETY

PROPOSED FOR ITS PRINCIPAL OBJECT

THE ELUCIDATION OF THE GEOLOGY OF YORKSHIRE,

AND LABOURED EARNESTLY IN THE PROSECUTION OF IT;

AND

THE REV. ADAM SEDGWICK,

F.R.S., F.G.S.

WOODWARDIAN PROFESSOR IN THE UNIVERSITY OF CAMBRIDGE,

WHOSE GEOLOGICAL CAREER BEGAN WITH RESEARCHES

IN THIS HIS NATIVE COUNTY;

THIS VOLUME

IS MOST RESPECTFULLY DEDICATED,

BY THEIR FRIEND AND FELLOW LABOURER,

THE AUTHOR.

ILLUSTRATIONS

OF THE

GEOLOGY OF YORKSHIRE;

OR A

DESCRIPTION OF THE STRATA AND ORGANIC REMAINS:

ACCOMPANIED BY A

GEOLOGICAL MAP, SECTIONS, AND DIAGRAMS,

AND FIGURES OF THE FOSSILS.

PART II.

THE MOUNTAIN LIMESTONE DISTRICT.

BY JOHN PHILLIPS, F. R S., F. G. S.

PROFESSOR OF GEOLOGY IN KING'S COLLEGE, LONDON; ASSISTANT SECRETARY TO THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE; SECRETARY TO THE YORKSHIRE PHILOSOPHICAL SOCIETY; HONORARY MEMBER OF THE ROYAL GEOLOGICAL SOCIETY OF CORNWALL; THE PHILOSOPHICAL INSTITUTIONS OF YORKSHIRE, LEEDS, HULL, WHITBY, SHEFFIELD, HALIFAX, AND NEWCASTLE-ON-TYNE; OF THE NATURAL HISTORY SOCIETY OF NORTHUMBERLAND, DURHAM, AND NEWCASTLE; NATURAL HISTORY SOCIETY OF SHROPSHIRE AND NORTH WALES; OF THE SOCIETY OF ARTS FOR SCOTLAND.

"Fungar indicis partibus."—*Plinii Epist.*

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INTRODUCTION.

BEFORE engaging in the study of this Volume, it may be useful to the reader to know what is the object it professes to attain, and what have been the means and endeavours of the Author for the fulfilment of his plan. A systematic view of the Mountain Limestone formation in Yorkshire especially, and in the North of England generally, under all its varied relations, is here attempted for the purpose of establishing a common standard, and local truths, to which the phenomena of analogous rocks in other districts may be compared.

It may reasonably be demanded why is the Yorkshire series of mountain limestone selected for such an object, and how has it happened that the Author of this Volume has become responsible for the execution of such a labour. The Book itself will, it is believed, supply a satisfactory answer to the first inquiry by shewing that no more comprehensive type of mountain limestone can be found in England than that which exists in Yorkshire, under circumstances of physical geography remarkably favourable to exact research. In consequence of this clear and complete development, the *method of variation*, by which the simple type of Derbyshire passes into the complicated group of Northumberland, is clearly traced in Yorkshire; the numerous organic exuviæ have been successfully collected; and the effects of great subterranean disturbances correctly appreciated.

The laws of these phenomena, rightly determined in this particular region, will indicate the problems which remain to be solved in other districts, before the beautiful fragments of geological truth, which are

disclosed by topographical research, can be united in a general history, and referred to laws of causation.

These advantages, combined with others depending on large area and geographical position, appear to justify the adoption of the Yorkshire series as a general type or standard of comparison for the limestone deposits of Europe.

I must not hope that in working out the magnificent problem attempted in this Volume, my efforts have been uniformly successful; but I am anxious to escape the imputation of having undertaken a task of great difficulty and importance without adequate preparation or peculiar advantages.

In 1819, I made, under the guidance of my Uncle, Mr. Smith, my first examination of the limestone of Yorkshire, and learned from Mr. Francis Gill of the Auld Gang Lead Mines the succession of the strata in Swaledale, for comparison with the very different series I had before seen at Bristol, in the forest of Dean, and near Pontypool.

In 1821, I made an active pedestrian tour of four months in the North of England; passing through the limestone tract of Derbyshire, and over the summit ridge of millstone grit into Yorkshire at Peniston; thence by Halifax, and the vale of Todmorden to Burnley, Colne, Skipton, and Settle. From Settle to Kirby Lonsdale, the line of the great Craven fault was attentively surveyed; at Kendal Mr. Todhunter's museum was consulted and Underbarrow scar examined. My route then led me to the limestone of Ulverston, and Egremont, and, in various walks round the lake district, the limestone border was examined at Lowther, Orton, and Kirby Stephen.

I crossed three times the Penine chain between Penrith and Aldstone moor, and spent some time in the examination of that interesting district; passed by Hartley burn to Gilsland wells; followed the basaltic line of the Roman wall; and turned by the North Tyne and the valley of the Reed toward Carter fell. After skirting the Cheviot beyond

Wooler, and returning by Belford, Alnwick, Morpeth, Newcastle, Ponteland, Corbridge, and Ebchester, to Durham,* my southward route passed by the West Pits, and, entering Yorkshire at Barnard Castle, continued by Brignall, Arkendale, Reeth, Leyburn, Masham, Ripon, Ripley, Harrogate, and Harewood, to Leeds. Here I found Mr. E. George engaged in the details of local geology, and employed myself in making a MS. geological map of the vicinity. After another visit to the mines of Swaledale, my wanderings closed at Nottingham.

In Jan. 1822, I accompanied my kind relative to examine the limestone country of Conishead priory (Ulverston), Cleator near Egremont, and Hesket-Newmarket. In August of the same year I walked from the east coast of Durham through Teesdale, crossing the great Penine escarpment by the Hilton mines, and rejoined Mr. Smith at Kirby Lonsdale. After spending many months at Hesket-Newmarket we returned again to Kirby Lonsdale, and from this delightful station explored minutely a large region of slate, limestone and millstone grit, and collected abundance of fossils.

In 1824, I walked from Kirby Lonsdale to York, chiefly following the valley of the Aire; and it was in arranging the small collection then belonging to the Yorkshire Philosophical Society, and in drawing for Mr. Smith's Lectures, that I first resolved to follow out the recommendation of the Council of that Society, and to devote a considerable portion of my time to the Illustrations of the Geology of Yorkshire. My lamented friend E. S. George walked with me to Greenhow hill, and through a part of Wharfedale—one of the most instructive short journeys I ever made, and the first in which I used the mountain barometer—an instrument of inestimable value, where exactness is desired in investigating a complicated series of rocks in a district like that of the Yorkshire dales.

* The observations made during this Tour in Northumberland were the ground-work of Mr. Smith's geological map of that County.

In 1825, I examined at leisure the limestone district of Castleton, and collected abundance of fossils. Parts of Wharfedale and Swaledale were afterwards reviewed; Wensleydale next drew attention, some of its branches were investigated with considerable minuteness, and many of the mountains ascended; drawings were made of waterfalls and contours of hills, and sections of strata measured.

In 1826, I became permanently attached to the Yorkshire Philosophical Society, and made a long pedestrian tour in Scotland. Arran was then viewed with a close scrutiny, and a catalogue drawn up of the organic remains of the peculiar carboniferous system there. I returned by Troon, Ayr, Cumnock, Sanquahar, and Dumfries, to Carlisle; crossed, for the fourth time, (by the new road then unfinished) the great limestone escarpment of Hartside to Aldstone moor; and descended Teesdale.

In 1827, I again visited Castleton, examined Dr. Henry's collection at Manchester, accompanied him to Primrose near Clithero, and with Mr. T. Thompson ascended Pendle hill, and partially explored the limestone tract of Bolland.

In the autumn of this year, a walk through the lake district with my friend Mr. T. George completed my survey of the Cumbrian slates, and a leisurely review of the Craven fault and its attendant phenomena enabled me to draw up for the Geological Society a memoir on that district which is printed in the Transactions, (New Series, Vol. III).

The year 1828 and part of 1829, were devoted to the preparation of the first Volume of 'Illustrations of Geology of Yorkshire.'

In the summer of 1829, I saw and contrasted the mountain limestone district of the Meuse and the transition limestone of the Eyfel, and examined the public collections at Ghent, Namur, and Bonn, besides the valuable cabinet of M. Heinkzelius at Maestricht; all of which were useful to my object. In the autumn of the same

year, my acquaintance with the South of England limestone was renewed by an examination of part of Mendip, and the gorge of the Avon at Clifton; I carefully inspected the collection of Mr. Miller now transferred to the Bristol Institution, the collection of the Bath Institution arranged by Mr. Lonsdale, the cabinets of Col. Houlton and the Rev. B. Richardson of Farley castle, Mr. Meade of Chatley, and the Rev. H. Jelly of Bath.

In 1830, I saw again, in company with Mr. G. W. Wood, the limestone tracts of Namur and Luxemburg, the Museums of the Netherlands, the rich and well arranged Museum of Strasburg, the public Collections at Geneva and Lyons, and the valuable Cabinet of M. De Luc.

In 1831 my leisure was almost wholly occupied by the preliminary arrangements of the First Meeting of the British Association for the Advancement of Science; but in the neighbourhood of Halifax I was enabled through Mr. C. Rawson to add materially to my knowledge of the lower coal system, and to demonstrate the occurrence of a marine (calcareous) bed with fossils of the mountain limestone among the coal series.

In the summer of 1832 I surveyed the vicinity of Harrogate, the whole length of Nidderdale, crossed over Great Whernside, explored the curious districts of Kettlewelldale, and Greenhow hill, and added to my knowledge of other adjacent tracts. In the autumn of this year, Swaledale and Arkendale were reexamined; and I measured every visible bed in Water crag, Lovely seat, Bear's head, Addleburgh, and many inferior hills, besides threading several glens.

In the spring of 1833, I again visited and measured almost every scar in Coverdale, Waldendale, Bishopdale, Simmer water, and all the head branches of Yoredale; revisited Kettlewell; crossed from Askrigg to Muker, walked over the summit of Swaledale, to Kirby Stephen; examined the curious districts of Mallerstang and Ravenstonedale; passed

by Orton, and Sedbergh, and through Garsdale to Hawes. Again I ascended Addleburgh, repeated observations at Askrigg, crossed the Stake, redescended Bishopdale, again crossed over Pen hill, and after clearing certain difficulties in Coverdale, once more walked to Hawes and redescended Wensleydale.

In the autumn of this year I reviewed Ribblesdale, ascended Penyghent, Fountains fell and Wharnside, and measured every visible bed in these noble mountains, in two or three directions (as I had done for Ingleborough and Penyghent in 1824 and 1827) and passed again through Dentdale, Ingletondale, and Kingsdale, to verify former notices.

Later in the year I again left home with my friend M. De Billy of Strasburgh, passed by Middleham, Leyburn, Bolton castle and Reeth, to Richmond; and, after some further research in Swaledale, walked to Mr. Witham's at Lartington hall, to join Mr. Salmond in a third tour of Teesdale. We gave much attention to the Whin sill and the Whin dykes from Middleton to the summits of Maizebeck and Troutbeck, twice crossed the Penine chain from Teesdale to Dufton, and followed the Eggleston Whin dykes to the north-east and east, being aided in the research by Mr. Stagg and Mr. Richardson of Middleton, and Mr. Prattman the proprietor and Mr. Forster the agent of Butterknowl colliery. I ascended Mickle fell and measured all its beds in two directions, saw the Tan hill collieries, investigated the intricate phenomena near Brough (Westmoreland), examined the country near Lartington with Mr. Witham, and Brough near Catterick with Mr. Lawson, and gathered new information near Richmond, Gilling, and Middleton Tyas.

In the summer of 1834 I reviewed the districts between Wharfedale and Nidderdale, and Nidderdale and Yoredale, for the purpose of completing my views of the millstone grit series, and the limestone of Upper Nidderdale. In the autumn of this year I saw some districts of basalt and limestone in Northumberland in company with Mr. Wm. Hutton and other friends.

In the spring of 1835 I made a very satisfactory examination of the low Craven country between Settle, Skipton, Colne, Burnley, Whalley, Stonyhurst, and Slaidburn; carefully reviewed the Bolland limestone; and the vicinity of Craco, Burnsall, and Bolton bridge.

In London I examined minutely the fossils collected from the mountain limestone of Ireland, by Mr. Weaver and Sir Philip Egerton, Bart., amongst which were some new species, and many which had become familiar to me in the North of England. I also saw some of Mr. De la Beche's fossils from the limestones of Devonshire, and (a second time) the greater part of Mr. Murchison's treasures from the Silurian system.

Previously to the Meeting of the British Association in Dublin I had opportunities of greatly improving my knowledge of the Irish mountain limestone, and profited by the communications of Mr. Griffith, Capt. Portlock, Professor Scouler, and the collections of the Rev. S. Smyth, Dr. Greene, and Mr. R. Hutton, and received valuable donations of specimens from Dr. Sadlier and Mr. H. Hutton.

After the Meeting a party of geologists assembled at Florence Court, the hospitable mansion of the Earl of Enniskillen, where Lord Cole's rich Collection was opened to me, and I could discuss the subject of this Volume with Professor Sedgwick, Mr. Murchison, Mr. Griffith, Sir Philip Egerton, and M. Agassiz. Expeditions to three of the fine mountains which are visible from Florence Court gave us a complete section of the limestone series in Ireland; and while the forms of Ben Jochlin, Kulkeagh, and Belmore, seemed copied from Penyghent, Wild Boar fell, and Water crag, their constituent rocks were found closely analogous.

Enriched with specimens, drawings, and new knowledge from this interesting region, I returned home to prepare my publication. I have however found it necessary to make two additional journeys, in one of which I have again surveyed Colsterdale, Coverdale, Kettle-

welldale, and Littondale; again crossed Hardflask and Malham moors; walked down Airedale to Skipton; and by Bolton, Blubberhouses, and Harrogate, traced the divisions of the millstone grit.

In the course of so many pedestrian journeys most of the high mountains have been ascended, and nearly every valley explored; the thicknesses of the strata having been ascertained by above one thousand barometrical observations.

I hope the preceding sketch of my proceedings will be thought to justify my publication; the nature of the subjects investigated, the necessity of close personal investigation of so many hills and dales, combined with that want of leisure, which so fatally retards the progress of men devoted to science, must be my apology for the long delay of its appearance.

I turn with pleasure to record the assistance which has been furnished me by several friends, whose names are not mentioned in the preceding pages. The mines of Greenhow hill were described to me on the spot by Mr. Nathan Newbold and Mr. Watson; Mr. Barratt supplied me with notes of those at Grassington, Mr. Stagg obligingly answered some queries concerning the mines which are under his able direction in Teesdale, and additions to my knowledge of the veins of Aldstone moor and the neighbouring districts were received from Mr. Sopwith, Mr. N. Wood, Mr. H. L. Pattinson, and Mr. Wm. Hutton. Notices of the limestones of Craven have at different times been communicated to me by Mr. Preston of Flasby, and Mr. Hamerton of Hellifield Peel; Mr. Yorke of Bewerley afforded me every facility for my inquiries in Nidderdale; Mr. Wheeler of Barnard Castle, Mr. Rutter of Middleton in Teesdale, Mr. Jonathan Otley of Keswick, and the late Mr. Bland of Hilton, have given me local information. My best thanks are due to Mr. Hodgson of Lancaster, for prompt and complete information respecting the curious coalfield of Ingleton and Burton.

I am greatly obliged by the prompt attention of Mr. Gibson of

Hebden Bridge, and Mr. Francis Looney of Manchester, in sending specimens of many fossils from new localities in the limestone shale of the vale of Todmorden. Mr. Cooke forwarded for inspection the results of his researches in the vicinity of Hesket and Wigton, and Dr. Moore several select specimens for comparison and engraving.

But my greatest obligation is to MR. GILBERTSON of Preston, a naturalist of high acquirements, who has for many years explored with exceeding diligence and acumen a region of mountain limestone remarkably rich in organic remains. The collection which he has amassed from the small district of Bolland is at this moment unrivalled, and he has done for me, without solicitation, what is seldom granted to the most urgent entreaty; he has sent me for deliberate examination, at convenient intervals, THE WHOLE OF HIS MAGNIFICENT COLLECTION, accompanied by remarks dictated by long experience and a sound judgment. He had proposed to publish an account of his discoveries, and especially of the Crinoidea for which no man in Europe had equal materials, and had made a great number of careful drawings for the purpose; but all these, as well as the specimens, he placed at my disposal—a striking proof of liberal and genuine devotion to science.

An attentive examination of this rich Collection rendered it unnecessary to study minutely the less extensive series preserved in other cabinets. The Yorkshire Museum contains a considerable number of fossils from the limestone districts, chiefly presented by Mr. Danby, Mr. C. Preston, Mr. Kirby, Mr. Smith, Mr. Salmond, Mr. Roundell, the Rev. D. R. Currer, Mr. Hamerton, the Rev. W. V. Harcourt and myself. The same Museum contains a fine suite of fossils from the Northumberland limestones presented by the Rev. C. V. Harcourt. The Collections of the Natural History Society of Newcastle-on-Tyne have also been of great service to me. In addition to these advantages my own cabinet has furnished a few rare species; most of the figures of fossils are taken from specimens in Mr. Gilbertson's Collection, because these were generally the best that could be found.

Very few and slight notices concerning this district have reached the Philosophical Societies of Yorkshire; the maps of Mr. Smith and Mr. Greenough are still the only graphical representations which can be consulted, (for Mr. Hall's Lancashire map only reaches the border of Craven,) and the memoirs of Professor Sedgwick and Dr. Buckland on the Penine chain, of Mr. Winch on the Geology of Northumberland and Durham, and of Professor Sedgwick and Mr. Hutton on the Whin sill, with my own Essays in the Geological Transactions and Encyclopædia Metropolitana, contain nearly all the geological information that has been even partially given to the public.

Mr. Nixon has inserted in the Philosophical Magazine and Annals, some of the results of his exact trigonometrical and barometrical measures of the Yorkshire mountains; these, combined with the results of the Ordnance Survey and some of my own measures, will be found under the proper head. The labour of reducing my numerous barometical observations was lightened by the assistance of my friend Mr. Wm. Gray, jun.

I acknowledge with pleasure the useful information which I have received concerning the metalliferous veins of Cornwall from Mr. Henwood, and those of Flintshire from Mr. John Taylor.

It has been my wish, to make just mention in the preceding notices of every individual who has accompanied me in my walks or in other ways specially aided my work; those who have in a less direct manner interested themselves in the publication are by far more numerous, including nearly all the eminent cultivators of geological science. Among these I may be permitted to signalize one, the most competent of all men to have undertaken the description of this his native district, and whose labours on the borders of it rank among the best efforts of English geology. Professor Sedgwick's examinations of the North of England have the same date as my own; we met for a few moments near the High force in 1822; after ten years of independent research we compared results at Cambridge, and I found with great satisfaction that my

conclusions, drawn chiefly from examining the interior of the district, were consonant to those of my distinguished friend derived chiefly from the western border.

A valuable contribution to the philosophy of geology, by Mr. Hopkins, has just been printed for the Cambridge Transactions, and it is with extreme gratification that I find the *deductions from mechanical principles*, as to the direction and other circumstances of the fissures and displacements of rocks, contained in this interesting Essay, perfectly in accordance with the *inferences* or *laws* of *phenomena* to which observation had conducted me. Had Mr. Hopkins's demonstrations in Geological Dynamics, been known to me before the Chapter on Subterranean Movements, (p. 99, &c.) was printed, my views could not have been adduced, as it appears to me they ought now to be, in confirmation of his very important conclusions. The remarkable result arrived at by the tabulation of my observations on the Symmetrical Structure of Rocks, (Chap. iii. p. 90.) of two positive and two negative axes of fissure, the axes of each pair respectively perpendicular to one another, was totally unexpected when the table was composed, and no other observations or investigations for the same object being published, prudence suppressed speculation; but I do not think the causes of the symmetry represented in the Diagram p. 98, beyond the scope of Mr. Hopkins's researches.

The excellent work of The Messrs. Sowerby, entitled the Mineral Conchology of Great Britain; Martin's Petrificata Derbiensia; Parkinson's Organic Remains; Miller's and Cumberland's works on the Crinoidea; Dr. Ure's Rutherglen; and some figures of Orthoceratites communicated to the Annals of Philosophy by Dr. Fleming; contain nearly all the graphical representations of mountain limestone fossils accessible to the English reader.

It was important to supply this deficiency, by a large series of characteristic figures; and it is with a sense of real obligation that I mention the name of Mr. Lowry, who, in engraving from my draw-

ings, has exhibited not only distinguished talent and judgment, but a patient and vigilant attention peculiarly valuable to one whose leisure hours are so few as mine.

To the numerous friends of geological science who have subscribed for the publication of this Work, unfeigned thanks are due: the personal favour conferred on the Author he gratefully acknowledges; but a higher feeling is involved in the spontaneous patronage which has been conferred on this record of his exertions, by individuals not specially interested in the results. These disinterested promoters of science know that without such aid and sympathy many costly works would never have appeared; many of the discoveries of the present age would be unknown to the next; and the progress of knowledge would be fatally retarded.

The noble aspiration of Wordsworth—

> Enough, if something from our hands have power
> To live, and act, and serve the future hour,—

is peculiarly applicable to the labours of men of science; and it is with a full sense of the importance of the trust which has been reposed in him for this object, that the Author of the Illustrations of the Geology of Yorkshire delivers the conclusion of his Work.

York, *March* 1, 1836.

CHAPTER I.

Description of the rocks deposited in water.

SLATE SYSTEM.

THE lowest stratified rocks visible in Yorkshire, or at any points on the line of the Penine chain, are portions of the great system of argillaceous rocks usually classed as grauwacke and clay slate. Since my memoir on these rocks in Craven was presented to the Geological Society (in 1827), the researches of Professor Sedgwick and Mr. Murchison have cleared away much of the obscurity which involved the history of the older sedimentary deposits, and established amongst their higher groups a definite order of succession. Nearly all the argillaceous rocks in the British islands, inferior to the old red sandstone, may be arranged in the following scheme, and it is already probable that the rocks of Brittany, the Harz, the Eifel, and Norway may be subdivided in a similar manner.

		Names of Formations.	*Occurrence in the North of England.*
Silurian System (Murchison)	3	*d.* Ludlow rocks ...	Near Kirby Lonsdale.
		c. Dudley limestone ..	Unknown in North of England.
		b. Caradoc sandstones	Unknown in North of England.
		a. Builth rocks ...	Supposed to be known in Ribblesdale.
Grauwacke or Cambrian System (Sedgwick)	2	*c.* Plynlymmon rocks	In Hougill fells.
		b. Bala limestone ...	Coniston Waterhead.
		a. Snowdon rocks ...	Langdale, Scafell, &c.
Clay Slate or Skiddaw System	1	*c.* Clay slate ...	Skiddaw, Grasmere.
		b. Chiastolite slate ...	Skiddaw, Bowscale fell.
		a. Hornblende slate...	Skiddaw.

Chlorite schist, mica schist, and gneiss, generally occur below the slate system, but are scarcely known in the north of England.

The slate series of the north of England is less complete than that of the border of Wales, in respect of the Silurian system, but all the other terms are as well shewn around the Cumbrian lakes, as in the principality: the whole series dips generally to the S. E.

1. Upon the granite of Skiddaw forest, rest in succession, first, some gneiss and mica schist, then hornblende and actynolite slate, chiastolite slate, and finally, dark clay slate, without the least trace of conglomerate. The hills have a gentle outline, and the rills run down in straight lines, and meet at acute angles.

2. *a.* On the margin of Derwent water the second system is seen lying upon the Skiddaw slate, and presenting new mineral and physical characters. The lowest of its beds is a red mottled, apparently fragmentary, argillaceous rock, locally confused with porphyritic and amygdaloidal irruptions, sometimes associated with or changing to a green brecciated mass, traversed by vertical planes of slaty cleavage. Over this is an almost infinite variety of bedded rocks of a green, gray or dark colour, mostly of slaty structure, not unfrequently altered in aspect and composition by the local action of irrupted igneous rocks, or by a more general effect of pervading subterranean heat. Brecciated, amygdaloidal, and subporphyritic rocks, often slaty, diversify this region, which includes the noblest and most picturesque mountains, the loftiest precipices, and grandest cascades, in the district of the lakes. No organic remains have yet been found in it, for comparison with those of Snowdon.

2. *b.* It is bounded on the S. E. by beds of limestone containing locally (Coniston Waterhead, Broughton) abundance of organic remains, alternating with dark argillaceous slates. This is believed to be coeval with the limestone of Bala in North Wales.

2. *c.* The uppermost member of this system, resting on the limestone, has more of the ordinary aspect of grauwacke slate, and is not at all confused by intermixture of porphyritic and other anomalous masses. Its rhomboidal surfaces which strike the eye in the country of Hougill fells, and Shap, and in the sides of Windermere, and Coniston water, the alternations of massive sandy and laminated argillaceous beds, which occur so frequently in these localities, and the general relations of the rock, remind us forcibly of the district of the Lammermuir in Scotland; of the county of Down in Ireland; the Berwyn mountains in Wales; and parts of the grauwacke slates of Devonshire.

3. *a.* The Ribblesdale slates, which are presumed to represent this series, will be described hereafter.

3. *d.* Except in a small corner of the district near Kirby Lonsdale, there is perhaps no trace of the occurrence of the upper Silurian system in the vicinity of the Cumbrian lakes. Here it appears in the state of a dark reddish, or pale slaty, or flaggy rock, micaceous, sandy, or argillaceous, and containing organic remains in nests and lines parallel to the laminar surfaces, and partially associated with calcareous matter. It is almost certainly a part of the Ludlow rocks of Mr. Murchison, and contains some of their fossils. Occurring on the extreme point of the district, and on the dip side, we have no hope of finding it more developed in any part of the north of England. (*See Diagram, No.* 1, for the relation of the Cumbrian slates to the Penine chain.)

Such are the terms of the series of slaty rocks in the north of England. We may now turn to consider the circumstances under which some of them approach to the borders, or enter the interior of Yorkshire. The general direction (strike) of the slaty beds in the western Cumbrian district is N. E. and S. W., and this direction is not materially changed in any quarter by the many irruptions of pyrogenous rocks. In the eastern parts it turns more to the east, as the Skiddaw slate from Keswick to Matterdale, the Coniston limestone from Windermere to Shap Wells. The general dip being to the south east, we see the reason why it is only near Kirby Lonsdale that the uppermost beds of the whole series (Ludlow rocks) shew themselves.

The Cumbrian slaty district is longest in a direction from N. W. to S. E., and is completely surrounded by more recent deposits. From Egremont to Low Furness its boundary is principally formed by new red sandstone, running S. S. E. across and over the ridges of slates; from Egremont by Cockermouth, Hesket, Pooley bridge, Shap, Orton, Ravenstonedale, Sedbergh, Kirby Lonsdale, and Kendal, to Ulverstone, mountain limestone, with occasional interventions of red sandstone and red conglomerate, forms a nearly continuous though irregular border, and rests unconformedly on the different members of the grauwacke. At some points, especially near Ulverstone, this border is broken, and grauwacke forms seacliffs. But the most interesting interruption of the limestone border is found near Kirby Lonsdale, where, in consequence of the effect of the great Penine fault, the Hougill fell slates

pass S. by W. between two edges of limestone, and then turn E. S. E., in a narrow band between the same edges prolonged for a distance of about fifteen miles. On the line of the northern part of the Penine fault a similar but less extensive ridge of slate rocks appears, and forms the remarkable conical hills called Murton pike, Knock pike, and Dufton pike, which stand like buttresses below the great escarpment of Scordale head, and Cross fell. The great line of fault is here N. N. W., and its dip nearly E.; the slate masses appear in a situation where the relative elevation of the limestone beds is the greatest, and from whence northward they begin to acquire a partial dip toward the Tyne, and soon experience along Lunedale a great depression to the south. By these inclinations the slate rocks are soon concealed both to the north and the south; and their whole range is less than ten miles.

The appearance of the slate rocks along the Penine chain is thus certainly traceable to the operation of subterranean movements subsequent to the deposition of the carboniferous system, and the occurrence of greenstone dykes in connection with each tract, (near Dufton, and at Ingleton), and of a remarkable red granitoidal porphyry at Dufton, leaves no doubt that these movements were accompanied by the ejection of igneous rocks.

As the grauwacke and carboniferous systems are wholly unconformed to each other, the slaty rocks along the Penine chain belong to different parts of the grauwacke system, and exhibit much diversity. The northern pikes are mostly formed of a soft dark rock, which has nearly equal analogy with the upper slates of Skiddaw, and some of the soft lower parts of the Hougill series; in Murton pike quartz veins are extremely abundant. No organic remains have been found in these rocks. The elevation of the pikes is about one thousand feet.

The grauwacke rocks of the country from Hougill fells to Kirby Lonsdale exhibit considerable variety both as to structure and texture, and it seems probable that these differences correspond in part to difference of geological age. The lower grauwacke series of Hougill

fells, includes dark flaggy beds, lighter coloured laminated, and solid grauwacke of fine grain, and greenish or dark colour, with numerous long intersecting joints, producing extensive plane surfaces in various directions. The upper portions in Barbon fell, Casterton fells, &c. include more of those thick arenaceous beds, which, near High Borrowbridge and in Long Sleddale, diversify the laminar grauwacke, and make some approach to common close grained sandstones.—Any thing like the coarse quartzose grauwacke of the Lammermuir in Scotland, the Longmynd in Wales, and the Cavan district in Ireland, is very rarely seen on the south-eastern side of the Cumbrian slaty region. No organic remains have yet been found in these rocks. The highest point of Hougill fells is 2160 feet; Middleton, Barbon, and Casterton fells exceed 1000 feet. Whether these arenaceous rocks pass by insensible gradations into the fossiliferous 'Silurian' beds of Kirby Lonsdale, is not easily known; those beds occurring only on the western or downcast side of the Penine fault, in a low country much obscured by superficial detritus.

Following to the east south-east, the course of the narrow band of slate rocks, subjects of great interest present themselves. As before observed, this band runs, almost for its whole length, between lines of limestone, the northern being the returning and continuous edge of the horizontal beds in the elevated Penine region; the southern being a narrow line of rocks set on edge or dipping violently to the south, so as to suggest the idea of a great fracture taking place along the line of slate rocks, having that line as its axis, and producing an angular downthrow to the south, the superficial rocks having been wholly removed along the line of disturbance. *(See Diagram, No. 2.)*

A parallel fault on the south side, also causing a downthrow in the same direction for a length of thirty miles east of Kirby Lonsdale, indicates the intensity of the forces concerned. The slates seen along the range of this narrow band vary much, and deserve particular notice, in consequence of the light they appear to throw on that very obscure subject, the cleavage of slate. The great limestone plateau, which sup-

ports Wharnside, and Ingleborough, and Penyghent, rests uniformly on a nearly level surface of grauwacke, without the intervention of any red sandstone; the lower beds of the limestone contain, among corals and shells, large and small worn lumps of grauwacke, through which, as well as through the mass of limestone, the joints and cracks pass. For miles in length the junction may be seen distinctly, and certainly nothing can be more striking than the contrast of the variously directed fissures, joints, and laminæ, of the supporting slate, with the horizontal beds and vertical joints of the limestone entablature.

On viewing the intersecting planes of these joints, in a quarry or other favourable exposure, it is difficult to resist the impression that they meet one another with almost geometrical regularity: we measure the angles and find on a horizontal plane the edges of three systems of divisional planes, crossing one another at definite angles; the inclinations of these planes to the horizon is constant, and a little knowledge of solid geometry suffices to determine the form of the supposed crystal of slate.—But on entering the next quarry, some variation is observed in the measures, and by prosecuting the inquiry we commonly pass to the other extreme, and believe that all this seeming regularity is illusory. Three horizontal floors of fine grained slate were measured in Leck Beck near Kirby Lonsdale in 1823, and it was found that on one of these existed four sets of parallel edges arranged two and two, the one couple crossing at angles of 68° and 112°, the other at right angles. One of these sets of parallels was considered the cleavage, it was found to be crossed by the others at angles of 47°, 90°, and 115°. On another slab the cleavage was crossed at angles of 44° and 90°; in the third they were 54°, 90°, and 146°.

In the extensive quarries above Ingleton, the cleavage planes preserve one constant course to the S. E., dipping slightly to the S. W.; cross joints run vertically to the N., and oblique joints dip N. E. The stone is mostly of a fine texture and green colour within, though often purple on the surfaces; but a hard granular not fissile variety, called 'galliard,' sometimes intervenes in elongated nodules and bands

parallel to the planes of cleavage. There is in some places a more frequent alternation of the finer and coarser varieties, and in such cases it is interesting to remark that the numerous cross quartz veins in the latter cease without penetrating the former. Certain cleavage planes are covered by arborescent films or *cubical* crystals of iron-pyrites imbedded by some of their square faces in a parallel coating of a fibrous zoolitic mineral, which occasionally softens by exposure into nacreous laminæ. In some layers of slate, minute *polyhedral* crystals of pyrites are disseminated; in others the spaces they occupied are filled by a black powder.—The slates are crossed by a set of secret parallel divisional planes called 'bate.' In Clapham dale the slaty laminæ range nearly east, and dip 60° S. In the valley of Wharfe, besides a large quantity of granular rock, slate is seen in great abundance, under the level limestone, with laminæ of cleavage directed E. S. E., and dipping 45° S. S. W. In Ribblesdale the slaty rocks are widely expanded, and are worked at many points for roofing, and flagging, and perhaps finer stone of the kind is no where known. It is quarried in a peculiar manner, with attention not only to the structure of the rock but also to the situation, and dryness; for these circumstances are found to have influence on the quality of the stone. In all the quarries hereabout, whether under the limestone scars, or in the midst of the slaty region, two constant sets of parallel divisional planes divide the whole rock into rhomboidal prisms, lying horizontally, and joints, vertical, oblique, and horizontal, truncate these prisms variously. (1) Of the two sets of planes, one called 'spires,' by the workmen, is very obvious, and divides the rock into tables of great extent and uniform thickness, which are sometimes separated by a little soft greenish substance. (2) In one quarry the other scarcely visible planes called 'bate,' by the workmen, cross the spires at an angle of 51°, (39° on the ends of the tables,) and while *they* dip 71° N. N. E. and range E. S. E., *these* dip 70° S., and range nearly E. and W. The 'bate' may be looked upon as the secret laminar structure of the stone, which is occasionally developed by weathering to an obvious degree. (3) Vertical joints called 'ends,' cross both spires and bate; and in the quarry now referred to they meet the spires at angles of 84° and 96° nearly,

(81° and 99° measured on a horizontal plane.) (4) Other vertical joints of less continuity also pass through the tables. (5) Oblique joints are frequent. (6) There are also horizontal and undulating and slightly inclined joints or floors, which are of short and uncertain extent, affecting some tables and not others. (7) There is yet another set of planes in this singular slate called 'rows,' which generally present a few parallel edges on the tables, and pass with different degrees of inclination to the horizon through their substance. In the quarry from which the preceding details are drawn, they dip N. N. W., and cross all the other planes, sometimes appearing to effect a small displacement, so that they are a kind of faults.

For the sake of distinctness the above description has been taken from one quarry. The most constant circumstances of structure are three. The strike of the 'spires' is E. S. E.; that of the 'bate' is about E.; and that of the 'ends' nearly N. The same 'strike of the spires' is noticed in most of the quarries under Moughton Scar, but the dip there is 70°, 45°, and 80°, S. W. by S. The same direction is also seen on the east of the Ribble, with a dip of 45° S. S. W., and at a point further north, with a dip 15° to N. N. E.; the same direction of the cleavage planes has been noticed in Leck Beck, Ingleton, Clapham, and the valley of Wharfe, and always with a dip to the S. S. W.

Is this rock stratified? what are the planes of stratification? To these questions in 1827, after exceeding labour and reflection, I did not venture to offer a reply; and though since that time I have repeatedly examined this district, with the advantage of knowing Professor Sedgwick's sentiments, it is with some hesitation that I adopt an opinion. Taking the clearest case first, there appears sufficient evidence in the quarries and other exposures in Ribblesdale, (Come Wood, under Moughton Scar, and Flat Rocks,) to establish for that part of the slaty range, the conclusion, that the 'spires' are planes of stratification, and the tables, or flags, true laminæ of deposition. The following is the evidence:—1. Alternations of soft substances between the flags. 2. Parallel layers of pyritous 'galliard' rock. 3. Small septaria and hard

nodular substances, sometimes pyritous, often sparry, with portions of orthoceratites and lituites, in the substance and on the surfaces of the tables. 4. A discoverable laminar structure of the tables, parallel to their surfaces, *which does not however allow of cleavage.*

Supposing this evidence sufficient, there appears reason to admit the cleavage planes of the Ingleton slate, to be coincident with the stratification, because of the similar interlamination of the galliard. It must follow that the 'bate', of the Ribblesdale flags and Ingleton slate, is the only representative here known of those 'cleavage' planes in the older slate rocks, which in Borrowdale, on Ulswater, in Langdale, in Charnwood forest, from my own observation, and throughout North Wales, on the testimony of Professor Sedgwick, I maintain to be transverse, (but not rectangled), to the stratification.

Upon the view here advanced, we can not avoid admitting some remarkable deductions. 1. The great change of mineral character and structure in the slaty rocks along the same, or nearly the same, lines of stratification, as between the Ribblesdale and Ingleton slate. 2. The complete overthrow of the slate rocks to nearly vertical positions, and the subsequent wearing down of their surface to a remarkably even plane. 3. The great thickness of these rocks, which in Ribblesdale can not be less than two miles.

With regard to the value of the Ribblesdale flags, it is to be observed that so many deteriorations from joints, rows, nodules, &c., make the opening of a quarry rather a hazardous speculation, especially as it is known from experience that the separation of the tables or flags goes only to a moderate depth, and that these coalesce sooner in dry ground than where the rock is bathed in water.

CARBONIFEROUS SYSTEM.

THE Cumbrian slaty group of sandy rocks, fine slates, and flags, with its limestones, and various porphyritic and conglomerated ad-

mixtures, having been long deposited and consolidated, extensive subterranean movements, connected with others probably of the same date in Scotland, Wales, and Ireland, happened beneath this district, and produced the general effect of throwing the strata on edge, in directions N. E. and S. W., and dipping S. E. Thus an irregular island appears to have been formed in the ancient ocean; and, at the same period, the Grampians, the Lammermuirs, the northern slaty and schistose tracts in Ireland and Wales, and the Ocrynian chain of Cornwall, stood above the waters. The proof of this is more satisfactory in the case of the Cumbrian and Scottish mountains, than in the other instances, because the newer deposits of the carboniferous system encircle or border on both flanks their slaty ranges, but never ascend far into the interior; and in the country of the English lakes we see plainly, from the manner in which the mountain limestone mantles round the edges and ends of the slaty ranges, the general direction of the shore of the ancient sea. If any proof were wanting to add certainty to the conclusion that not only the slaty rocks had been displaced before the deposition of the carboniferous system, but in part elevated above the action of the sea, it is found in the character and situation of the lowest member of the carboniferous system, and in the nature of the vegetable remains which especially belong to that system. For the lowest rocks referred to are conglomerates of such extent, and so situated, as to be referrible only to floods acting on the slaty rocks, and the plants grew on dry land.

The carboniferous system of strata derives its name from the most characteristic of its products, coal, which in different countries lies in different parts of the series. Not that every part of this series is productive of that valuable substance, but, in agreement with the well understood principle of geological classification, all the members of it are so related as to constitute (in England) one natural family of rocks, which is named from the most important of its members.

The classification of this system, most suited to the North of England, is contained in the following table; which likewise expresses

the relation in this respect of other parts of England, Scotland, and Ireland.

	North of England, and Scotland.	*Derbyshire, North and South Wales.*	*Belgium, and South of England.*	*Ireland.*
COAL FORMATION	Coal, shale, grits, and ironstone	Coal, shale, grits, and ironstone.	Coal, shales, grits, and ironstone.	Coal, shales, grits, & ironstone
Transition series	*Millstone grit* (COAL) *Shale.*	*Millstone grit, or Farewell rock.*		*Kulkeagh grit*
CARBONIFEROUS LIMESTONE SERIES	Upper series. Limestone Gritstone Shale (COAL)	'Limestone shale,' (*Derbyshire.*)		*Kulkeagh shale* Kulkeagh limestone Loch Earn shales and grits
	Lower series of limestones (COAL)	Mountain limestone (*England.*)	Limestones and shales	Enniskillen limestone
Transition series	*Alternations of red sandstone & limestone*	*Alternations of red sandstone and limestone*	*Alternations of red sandstone and limestone*	*Alternating red grits and limestones*
OLD RED FORMATION	Red sandstones and red conglomerate	Red sandstones and conglomerates	Red conglomerate	Red sandstone and conglomerate

It is necessary, for the sake of a careful comparison between one country and another, to divide the larger groups of associated strata into convenient assemblages or series; but in doing this we must be ever mindful that our lines of division contain much that is arbitrary, and more that is merely of local application. The carboniferous system undoubtedly does permit itself, in almost all situations, to be considered in three series, characterized by the *prevalence* of coal, limestone, and red sandstone; and corresponding to some general physical conditions which anciently prevailed in the regions where this classification applies. But to draw hard lines of division between these groups is only possible in local cases, where geological *accidents* have broken the continuity of natural operations; for where on such accidents (whether arising from near or distant convulsions) have occurred, the three groups pass into one another, by gradual approximation of character, or repeated alternation of deposits. In Somersetshire the distinction of coal series and mountain limestone series is absolute; but in Yorkshire and the North of England, the two groups are com-

pletely united by intermediate and almost indefinite alternation of sandstone, limestone, shale, coal, and ironstone. Though in some countries the old red conglomerate shews no sign of union to the mountain limestone, yet near Bristol, round all the region of the Cumbrian slate, along the Penine chain, and in Tweeddale, the alternation of red sandstone and mountain limestone is a common and characteristic phenomenon. Such a series of strata is in fact double, and belongs equally to the superior and inferior groups; and instead of being considered *neutral*, or named as a *distinct* series, should rather be included in both, as indicated by the mode of arranging the brackets in the table just given.

Groups or series, quite distinct in their middle terms as limestone and shale, may yet *graduate* into one another, so as to leave no *line of demarcation*, but a band of *transition* deposits. This phenomenon depends on the same general principle as the union of deposits by *alternation*,—viz. a change of the physical conditions of the region; the difference between the two orders of effects produced in *one period*, may hereafter reveal to us the *geographical* circumstances of the deposits, especially their distance from the centre of the physical disturbance.

Transition groups formed by gradation or alternation of the terms of any series may be thus represented. Let c., l., r., stand for coal, limestone, and red sandstone.

Gradation of substance.		*Alternation of beds.*	
Coal formation	$= C + C + C$	Coal formation	$= C + C + C$
Transition group	$= \left\{ \begin{array}{l} c + l + c \\ l + c + l \end{array} \right.$	*Transition group*	$= \left\{ \begin{array}{l} l + l + l + l \\ c + c + c + c \end{array} \right.$
Mountain limestone formation	$= \} L + L + L$	Mountain limestone formation	$= \} L + L + L$
Transition group	$= \left\{ \begin{array}{l} l + r + l \\ r + l + r \end{array} \right.$	*Transition group*	$= \left\{ \begin{array}{l} r + r + r + r \\ l + l + l + l \end{array} \right.$
Red sandstone formation	$= R + R + R$	Red sandstone formation	$= R + R + R$

OLD RED FORMATION.

Throughout a great part of the North of England, the lower scar limestone rests on the slate rocks, without any interposition of the old red formation (Kendal, Ingleborough); in other districts, (Brough, Lowther, Ravenstonedale,) red, purple, and white micaceous grits and shales alternate abundantly with the lower limestone beds; and in some localities coloured clays, and conglomerate sandstones, occupy irregular spaces between the limestone and the slate.

It is chiefly on the evidence of intermediate geographical position, that these conglomerate and clay beds are admitted as belonging to the old red formation; for I am not certain that in any one locality they are really seen to lie beneath the mountain limestone. They are confined to valleys in the slate formation, where these approach the limestone; they never follow that rock to its escarpments on high ground; and no where rise to a great height above the sea, except in Mell fell, and other lower hills at the foot of Ulswater. The following localities may be indicated. North of Ulverston, red and bluish beds of gritstone and clays, dipping southward toward the limestone from the slate rocks of Coniston water. In the banks of the Lune, north of Kirby Lonsdale, conglomerate and clay beds appear, also dipping southward from the silurian beds and toward the limestone which declines in the same direction (toward the south). The same beds appear a little northward in Barbon Beck, near the vertical limestone, but not so as to shew their relations to it. They are seen in Casterton woods in such a way as to make it the most probable supposition that they dip under the limestone there. Similar beds are seen in the Rother, near Sedbergh, and in the Mint, near Kendal. In the lower part of Ulswater they abound, and form the rounded masses of Mell fell, and Dunmallet. At Dacre castle they decline from the slate country toward the limestone, so as to make it probable that they pass under it. The Lowther river, and some of its branch streams near Bampton, disclose similar beds between the limestone and the slate. Beds of conglomerate, much related to these, occur in the Hilton valley, near Appleby, between the limestone and the slate.

It is almost exclusively a *valley deposit*, though deeply cut through by the lower part of the valleys in which it occurs. It seems to have been formed during some period of disturbance affecting the region of the Cumbrian mountains, just as similar rocks along the Grampians and Lammermuirs are referred to similar, perhaps contemporaneous disturbances.

The characters of the conglomerate are plain and striking. Large and small pebbles of a brown colour, sometimes blue internally, in immense abundance are accumulated together, and partially cemented into vast irregular beds by red clay, red sand, or *calcareous spar*. The pebbles vary in size, number, and degree of cohesion to the matrix in different beds. With these alternate other beds of red and white clay and red sandstone, almost or wholly devoid of pebbles. They are but feebly cemented in the clay and sand, and may be detached by a blow of the hammer, leaving a concave, smooth impression. In some cases I have imagined that one pebble indented another. But when calcareous spar is the cement, as is common about Kirby Lonsdale, the compound is more firm and makes a pretty appearance. The pebbles which occur in this rock at Kirby Lonsdale are

Rarely.—Red limestone with lithodendra, a few crinoidal joints, and other organic bodies.
Blue limestone, with crinoidal joints, and a fragment of syringopora.
Hornstone compact, purplish.
Calcareous spar.
Conglomerate of fine grain, micaceous, with white effervescing particles.
Quartz pebbles, holding micaceous iron ore.
Abundantly.—Grauwacke, same as in the neighbouring fells of Casterton, Howgill, &c.

By this list will appear the limited extent of the current which brought together these pebbles,—no trace of granite, syenite, porphyry, greenstone, amygdaloidal slate, or any of the Cumbrian rocks which are remote from the valley;—the same data may perhaps confirm our belief that the rock is of higher antiquity than the limestone series,

for if it had been of the age of the new red formation, how could it happen that none of the limestones, gritstones, and shales of the then uplifted Penine chain, of the sources of Lune, or the neighbouring country should have found their way to this deposit? The few limestone pebbles really found in it may have been derived from the Coniston limestone in the Shap country, but this is uncertain.

Veins of calcareous spar traverse these beds, and sometimes divide the pebbles, as at Oban in Argyleshire, and in the Nägelflue of the Rigi. This proof of the posteriority of such veins to the rocks which enclose them, joined to the evidence afforded by the quartz pebble with micaceous iron ore, is of great value in limiting the question concerning the age of mineral veins.

Though, as before observed, the limestone is not any where in its higher ranges based on conglomerates, numerous and large fragments of grauwacke are often seen embedded in its lower strata, as in Kingdale, Ingleton dale, &c., and quartz pebbles, as at Underbarrow scar, Winder, &c. In a little stream descending from Moughton scar, nearly west of Horton, to the Ribble, the slate is covered by a series of beds which I did not find elsewhere. Immediately on the slate rests a layer of fragmented quartz and slate in a calcareous paste. Above are four feet of shale, containing an indurated bed; next, a bed, eighteen inches thick, of fragmented quartz and slate with pyrites; then two feet of lumpy shale; three feet of lumpy limestone; five feet of broad, laminated shale, which throws out the water. Limestone scars come on above. Conglomerate beds underlay the limestone of the Penine chain in Hartside, and Hilton Beck.

ALTERNATING RED SANDSTONE AND LIMESTONE.

This intermediate or transition group, until lately little noticed by geologists, is of great importance in all questions concerning the comparative age of unconnected deposits of the older mountain limestone series. My attention was first drawn to it in the neighbourhood of

Lowther castle, where it is extremely well exhibited, and extended by observations on the northern side of the lake district (1822). The streams near Brough, and Ravenstonedale, have also furnished me (1833) with correct information, and enabled me to perceive that, in their relations to the old red sandstone, the lower scar limestones of Yorkshire and Westmoreland may bear a close comparison with the rocks on the Tweed, and the Avon, and the northern parts of the limestone hills of Monmouthshire. When, many years ago, Mr. Westgarth Forster published his useful Mining Section, he was not aware of the great Cross fell fault, and erroneously imagined all the red sandstone of the great plain of Carlisle to be below the limestones of the Penine chain. Yet into the composition of the series of that magnificent escarpment, red sandstone beds do really enter. In the country round Brough great dislocations prevail, but it is easy to obtain in the Swinegill stream, proof of the occurrence of red and mottled grits and shales under the great body of the lower scar lime, and enclosing particular kinds of limestone. Omitting, at present, all notice of the curious faults, and axes of movement in this singular region, it will be sufficient to state that, on ascending this watercourse for some distance, we find lower, and still lower beds appear, till at last the whole section changes, and the escarpment of the *elevated* Penine region is reached. The following is a general view (in descending order) of these beds, dipping S. or S. E.

	Red grits, and clays, and white clays.
60 ft.	of limestone, red, yellow, and mottled.
40 ft.	Red grits, &c.
	Plate, reddish and black.
	Yellowish grit.
	Plate.
	Grits and plants (Stigmaria).
	Whitish sandy clay.
	Sandstone and plants.
	Plate, dark coloured.
	Sandstone and plants (Stigmaria.)
	Plate, black.
50 ft.	Red grit, laminated.

Red and black plates alternating.

50 ft. Red beds.

10 ft. Sandstone, gray, argillaceous, full of lepidodendra and stigmaria (laminated below, and with a sort of fire clay at top).

15 ft. Gritstone and black plate alternating.

60 ft. Very black plate, and ironstone balls, and courses.

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285 ft. Limestone, many beds, the top richly covered with foraminated and other corals, and some crinoidea of mountain limestone; sandstones and plates of great thickness occur below, but are not well seen. It is a curious fawn-coloured stone, traversed by veins of copper, barytes, calc spar, &c.

The section on the road from Kirby Stephen to Ravenstonedale is very satisfactory. The north-eastward dip here exposes in a few miles a great thickness of beds, and the comparative freedom from detritus of this front of Langdale fell allows them to be fully examined. At the summit of the road on Ash fell, the ordinary limestone includes a red fossiliferous limestone bed; and, about seventy feet below the summit, the limestone mass is seen in a long scar, resting on yellow and purple sands and sandstones without fossils. One hundred and fifty feet lower, limestone beds, with productæ, ten or twelve feet thick, appear under red sandstone and red clay. Thirty feet of red sandstone succeed; below are six feet of limestone with lithodendra and productæ. Red sandstone is repeated, and similar alternations of thin, mostly reddish, slaty, fossiliferous limestone, and much thicker beds of red sandstone, for one hundred and fifty feet more. Below this it is difficult, for sixty feet, to discover the stratification; but then flat red limestone beds appear, with spines of cidaris vetusta: limestone beds soon succeed, and continue for a thickness of at least two hundred feet, dipping N. E. 15° or 20° invariably. Much of this lower limestone is dark, with few fossils (a small terebratula was found). It holds pebbles of quartz. From below it rises the slate of Langdale fells, but the junction is obscured by alluvium. *(See Diagram, No. 3.)*

The same succession is traceable on the road from Orton to Tebay, and in the country round Shap, and Lowther castle, and occurrences

of red and speckled grits are common in the limestone series of Greystoke Park, Hesket-Newmarket, and other parts of Cumberland. Red beds occur in the lower limestone of Kirby Lonsdale. The iron ore of Cleator may be viewed as related to this series.

Similar phenomena are seen on crossing Carter fell, and at several points near the Cheviot hills, and the Transactions of the Natural History Society of Newcastle contain excellent details of the same kind, concerning the lowest carboniferous series of the Tweed. Mr. Milne has likewise given additional information on this subject, in his account of the geology of Berwickshire (Brit. Assoc. Reports, vol. 3).

It is remarkable that these *red* sandstones contain few or no organic remains, while in the same section at Brough, the *yellow* grits are even full of plants, and the *limestones* rich in animal remains. If the cause of this general absence of organic remains from the old red and new red sandstones can be cleared up, a considerable step will have been gained for inductive geology.

MOUNTAIN LIMESTONE FORMATION.

The mountain limestone may be considered as peculiarly a British rock; for its extent in our island is far greater than in all the rest of Europe. The study of it is full of curious interest, and the variations which it presents appear well calculated to suggest correct views as to the changing conditions of the ocean and land, during one geological period. Such views, once obtained, may be applied to other parallel cases, and thus, by slow degrees, may a steady light be poured upon the now dark problem of the ancient hydrography of the earth. No single locality or small district can yield an adequate type for this great and variable series of strata, which has one character in the south of England, another in the northern counties; and exhibits some new peculiarities in Ireland and Scotland. Yorkshire stands as a middle term, to which the extremes of the Northumberland, Cumberland, and Derbyshire sections may be conveniently referred: and the generaliza-

tions which result from that combination may be employed in determining the analogies and differences of the Irish, English, Scottish, and Belgian types.

Throughout Wales and the greater part of England, as in the South of Yorkshire, the mountain limestone requires no subdivision into groups; it is, in fact, one great calcareous mass, neither graduating into, nor alternating with, the coal deposits above; nor much connected in this manner with the sandstones below. Over a great part of Ireland only one thick limestone group is seen, but in the vicinity of Enniskillen an upper portion appears. The triple division adopted for Derbyshire, by Mr. Farey, rests on no better principle than a geological accident. But the north of England exhibits a transition between the limestone and coal formations, which in all the district north of the Aire and the Ribble becomes extremely complicated. In Yorkshire are two principal types of the mountain limestone series, as expressed in the accompanying diagram, both covered by the millstone grit group.

Northern series.		*Southern series.*	
Upper limestone group 1000 feet thick, and complicated	Limestone Coal Flagstone Limestone Shale	Upper limestone group comparatively thin, and simple	Black, laminated limestone, and shale
Lower limestone group	Partially divided by shales, &c.	Lower limestone group nearly undivided	

DISTRICTS IN WHICH THE SOUTHERN SERIES PREVAILS.

If a straight line be drawn from Jervaux abbey on the Yore, through Kettlewell on the Wharfe, to Ryeloaf hill near Malham, and thence continued westward to Lancaster, it will divide the Yorkshire limestone tract into two parts, remarkably contrasted in the character of the limestones. In the northern districts the lower limestone rocks are covered by a thick and complicated series of limestone, flagstone, shale, coal, &c.; in the southern, all the terms of this series

interpolated between the limestones vanish, and these are either united with the lower rocks, much altered in aspect, or reduced to nothing.

This generalization, the fruit of infinite labour, will enable us to classify the descriptions, so as to render them more clear and mutually illustrative than otherwise could be accomplished; a circumstance of great value in so variable a system of rocks.

Bolland.—Commencing our survey at the south-western extremity, we find the limestone occupying a considerable extent of country in the vale of the Hodder, in the district of Bolland; the general direction of the limestone strata is N. E. and S. W.; they fill oval spaces in a wide hollow, in the midst of a mountain country whose higher parts are capped by the millstone grit series, and the intermediate slopes and hills are formed of the Craven shales and grits. It is, not, however, merely because of this hollow that the limestone rocks come to day in the vale of Hodder; they are, in fact, uplifted; and an anticlinal axis, directed N. E. and S. W., may be clearly traced through their whole extent. The Hodder, after taking a S. W. course in the limestone region, from nearly its source to Wardley, quits it and turns at right angles to its former course, through the overlying shales, to join the Ribble, but the *vale of the Hodder* (considered as a natural district is prolonged to the S. W. The limestone continues in this hollow for a few miles farther, and may be considered as forming two oval districts in the same great valley of elevation: Chipping is nearly in the centre of one, and Slaidburn in the other. The Chipping district ends suddenly by a steep dip to the N., a little beyond Whitewell Inn. As before observed, it is covered by shale, in which are beds of black limestone yielding fossils (at Black Hall); its thickness is considerable (several hundred feet), but the bottom is no where seen. In the river banks at Whitewell Inn, some limestone beds, low in the series, alternate with calcareous shales, and both contain crinoidal remains. At Harbour, the upper part of the limestone is seen under shales, which as well as the limestone yield crinoidal reliquiæ. In the solid masses of limestone, caverns abound; petrifying waters are frequent; organic

reliquiæ are plentiful; calamine has been worked in the hill W. of Whitewell, not in a vein, but in the joints and cavities of the rock: lead ore has been wrought at Dunsop.

Parallel to the axis of these large oval tracts is another singular anticlinal ridge of limestone, at a place called Sykes, on the road leading from Whitewell to the trough of Bolland: the distance between these axes of elevation being about three miles. An observer proceeding on the road towards the trough of Bolland, finds the strata of gritstone and shale dipping N. W. (the road rising in that direction), till within a small distance of Sykes, the dip is then suddenly reversed; beds of shale pass out from under the grits; limestone rocks rise beyond at a high angle to a considerable altitude, and again descending as rapidly to the N. W., are covered by the same shales, over which, in the hills around, are the ordinary grit rocks. What makes this interesting case more curious, is the occurrence of a sparry lead vein, precisely in the summit of the anticlinal ridge of limestone. The range of this vein seems to be nearly N. N. E. *(See Diagram, No. 4.)* The limestone is cherty, and has interposed short beds of calcareous spar and pearl spar. At Ash Knot, two miles from the Slaidburn limestone, on the S. E., is another detached mass of lower limestone, also exhibited by dislocation, and marked by the occurrence of lead veins.

Approaching the valley of the Ribble, we find at Widgill, near Bashall, another detached mass of lower limestone, with abundance of fossils.

Ribblesdale.—In Lower Ribblesdale, the principal mass of this lower limestone lies about Clitheroe, where it shews itself in the castle hill and other points, ranging N. E. toward Downham and Rimmington, and dipping S. E. toward the ridge of Pendle hill. The Ribble flows in limestone from near Gundleton to above Eadsford bridge.

Most of the laminated dark limestones of Craven appear as much connected with the shale above, as with this lower member of the mountain limestone series. They may, in fact, be considered

as the feeble representatives of the upper limestone group of Yoredale. An excellent section of these beds is afforded in the quarry on the bank of the Leeds and Liverpool canal, near Thornton, where alternations of calcareous and argillaceous beds rest upon a thick mass of laminated and crinoidal limestone. *(See Diag. No. 5.)* The range of the beds here, as in most parts of the neighbouring country, is N. E. Similar beds, with the same *strike,* occur at Lawley, Rimmington, Twiston, Gisburn, Bradwell, Broughton, &c.

Lothersdale.—A very remarkable exhibition of these dark limestones appears in the narrow valley of Lothersdale, which is formed along an anticlinal axis, ranging nearly N. E., between hills of shale and grit. The limestone is dug in very large quarries, nearly in the middle of its range, where the general N. W. and S. E. dips are locally altered to N. E., and W. by N. (30°). The stone is hard, fine grained, thinly laminated, of a blue colour, and contains many *laminæ* of chert, and cross strings of calcareous spar. This latter circumstance is always observed near the contortions and other dislocations which are so frequent in the laminated shales and dark limestones of Craven. In the eastern quarry on the south side of the valley, occur veins of sulphate of barytes, ranging E. by S. *across the anticlinal axis,* and dipping to the south. The limestone cheeks of the vein are altered in character. Sulphate of barytes likewise occurs in many of the joints which range N. W. and S. E. The dip of the beds is N. E. 30°. Few traces of organic remains can be perceived. Shales and alternations of argillaceous limestone cover the rock. *(See Diagram No. 6.)*

Skipton.—A similar and more extensive exposure of the same dark laminated limestone occurs in the valley of elevation which ranges from Skipton E. by N. to Bolton Abbey. The sides of this valley are formed of the Craven shales, surmounted by millstone grit, dipping each way from the limestone ridge to the S. by E. and N. by W. The axis of elevation is crossed by certain transverse undulations of the strata ranging N. and S., accompanied by parallel slips, and sparry

and partially metalliferous veins. In the great quarry near Skipton, which is opened on the north side of the axis, with a dip N. by W. of 40° to 70°, a sparry vein, with many ramifying strings, ranges N. and S., and dips 45° ? to the E. That at Bolton (*See Diagram, No.* 7.) shews a very remarkable dislocation, ranging N. and S., accompanied by spar and lead ore. All the quarries display a very great mass of shales and limestones both compact and crinoidal, black and grey,—spar strings abound in the beds, generally running transverse to the surface of stratification, whether this be arched or inclined N. or S. In a small quarry E. of and very near the town of Skipton, a minor anticlinal ridge, running E. by N., or parallel to the main elevation, is cut across so as to allow of a careful study of this curious phenomenon. There is here seen one rectangular upward fold, ('saddle') between two relative depressions, ('troughs'), the flexure of both the upward and downward folds being by much most acute in the lower parts of the quarry, (*See Diagram No.* 8.), and becoming rounded and evanescent above, as if the bending force had been *laterally applied*, and the resistance to it comparatively slight in the upper parts. The anticlinal angle is 90°, the steepest and shortest slope of the beds is to the south, (50°), on which side also is the most violent return to a nearly horizontal condition. The lower beds of the section are limestone, thick, partly of a black colour, and partly crinoidal; the upper beds are shale, with some argillaceous limestone. Innumerable spar strings divide the beds, with an evident general tendency to be at right angles to their surfaces. 'Slickenside' faces appear on the beds of stone and in the spar veins, and the prevalent direction of these on the horizontal beds is N. and S., as if the beds had been made to slide laterally.

The great anticlinal elevation of Skipton appears to be a continuation of that at Thornton, whose range passes between Pendle hill and Clitheroe, and parallel to the lower Ribble. In the other direction it passes eastward along a characteristic and dislocated country, by Blubberhouses to Harrowgate, being in fact one of the most remarkable subterranean ridges on record. The Lothersdale ridge is prolonged

nearly in a parallel course on the line of the 'Rearing Beds'* of Barrowford, and Padiham heights, and Whalley; the millstone grit ranging from thence by Ormskirk to the sea, and dipping to the S. E., indicates the continuation of the same combined axes of elevation, while the coalfield of Burnley lies in a parallel depression on one side, and Longridge fell forms its boundary on the other.

Rylstone.—North of the Skipton anticlinal, and nearly parallel to it, is another very interesting line of elevated limestone masses, ranging from the limestone valley of the Aire, by Flasby, Craco, and Burnsall, to Greenhow hill. From Flasby towards the Wharfe, the limestone passes along a valley, continually expanding in area as it proceeds to the N. E., so as to unite with the calcareous masses of Wharfedale, and dipping in the most distinct manner beneath the shaly slopes and gritstone summits of the Rylstone and Flasby fells; on the north-western side it is covered by shaly hills connected with Ryeloaf. Its upper beds, as seen about Craco, are of the dark laminated stone, so frequent in the Craven country, and below are solid gray and blue crinoidal rocks. In passing along its southern border, toward Burnsall, the average range points E. by N., and the steep southern dip soon brings it, near the village of Burnsall, down to the Wharfe, which, here changing its course, continues on its edge as far as Appletree-wick. From Burnsall it extends E. by N., growing narrower continually to the anticlinal ridge of Nursa Knot. Between Nursa Knot and Greenhow hill is a depression of the limestone ridge, filled with shales and grits, called 'dead ground.' Its range is nearly N. N. E., and it is crossed by many veins. *(See the Map.)*

Greenhow.—The Greenhow hill ridge rises into two eminences, called Greenhow hill and Coldstones; from both of them the beds dip rapidly to the north and south, (the dip diminishing as the distance from the axis augments,) 40°, 30°, 20°, 10°. Many metalliferous

* See Whittaker's Craven, for an account of this local name.

veins cross the ridge, ranging E. or E. S. E., and are traversed by north and south lines of irregular cavities called 'gulphs,' which are full of broken portions of the bordering rock, and are said to 'ruin the veins.' Shales and grits of great thickness, inclosing a thin limestone, envelope on all sides the oval mass of Greenhow limestone, which is more than 100 fathoms thick, the bottom having never been reached.

Wharfedale.—From Appletreewick by Burnsall, Grassington, Coniston, as far as Kettlewell, the limestone so largely developed in Wharfedale conforms to the southern type. From Kettlewell downward to Litton dale, its area is narrow, and so continues on the left bank to Grassington, but on the right it expands considerably in Litton dale, and on the hills above Kilnsea, to connect with the great limestone plateau of Malham moors.

The thickness of limestone exposed between Kettlewell and Great Whernside is about 900 feet. According to my own observations, corrected in part by an account given me by the men employed in a mine on the bank of one of the streams which I explored here, the series downward consists of the following terms, (under grits and shales.)

		Fath.	*Ft.*	*In.*
Limestone, a hard sharp stone in nodular beds ...	...	1	0	0
Parting of shale				
Limestone, light coloured	...	1	3	0
Parting of shale				
Limestone, light coloured	Shelly and crinoidal limestone	6	0	0
Parting of shale				
Limestone, light coloured		10	0	0
Plate	...	0	4	6
Limestone, rather dark coloured, forming bold scars	...	13	0	0
Parting of shale				
Limestone		35	0	0
Fine gritstone, yielding flags occasionally ...				
Gray limestone (productæ in the lower beds) ...				

	Fath.	Ft.	In.
Blue limestone, very solid, full of large productæ, lithodendra, &c.	1	4	0
Red limestone, with encrinites and spiriferæ	1	0	0
Gray limestone, in bold scars	15	0	0
Black nodular limestone beds	0	5	0
Gray limestone, small-grained crinoidal, compact or splintery, white or gray, &c.	10	0	0
Thin bedded limestone	0	1	3
Various limestones, mostly compact, to the level of Kettlewell dale	55	0	0
Fath.	150	5	9

The limestone in the country about Kettlewell is often liable to a local change into a crystallized yellowish or brown dolomitic rock, full of ramifications and nodules and hollow cells of calcareous spar. The beds and joints in this 'dun lime,' for so it is called by the workmen, are very irregular, and the rock feels heavy. Altogether it resembles not a little the brown dolomitic rock of Gerolstein, in the Eifel. It is known to the miners that this 'dun lime' runs in lines north and south, destroying the productiveness of the veins through the whole mass of limestone. The courses of this metamorphic limestone are from a few feet to twenty or thirty fathoms in width. They are usually defined by a joint, pass down through all the beds, and sometimes produce pipe or belly veins of lead, which go horizontally between the neighbouring beds, but never enter the dun lime beds; these in such cases form a cheek to the metallic matters.

These dun 'courses' are said to throw the veins which run east and west, four or five fathoms laterally.

Nidderdale.—In this valley the limestone series is seen in Steen beck, and, with two interruptions, in the river Nid and its banks, from Angram to Lofthouse. The interruptions here alluded to are caused by conglomorate gritstones ('millstone grit'), which rest almost directly on the limestone, where it is thrown down by faults.

This gritstone corresponds to the lower grits of Greenhow, and the 'bearing' grits of Grassington; and is a rock of much geological interest, as affording a term of reference where one was much needed.

PASSAGE FROM THE SOUTHERN TO THE NORTHERN TYPE.

The essential difference between these contrasted types is caused by the interpolation of sedimentary rocks between the limestone beds in all the northern tracts, which hence exhibit a complication of system, a repeated intermixture and succession of the four substances, (limestone, gritstone, shale, and coal,) which form in Bolland and Derbyshire only one succession. *

The method of variation from one of these types to the other,—a very important subject of examination,—can be best studied in the neighbourhood of Great Whernside.

The relations of the limestone series, at Grassington, and Greenhow Hill, and in Nidderdale, must be first studied.

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* Such are usually described in geology as simple and compound series of rocks: but a more exact nomenclature may be conveniently applied. In the southern tracts the *same substances* occur as in the northern; but the *combinations* of them are many times repeated and varied. Now, as all words intended to characterize phenomena by reference to nature and number, may be formed upon algebraic analogy, we may consider the substances, as *quantities*, the definite combinations of these substances as *terms*, and any succession of these terms as *a series* of one, two, three, &c. terms. Hence arises the following nomenclature.

Monomeric series.—When the substances occur only once, or in one compound term, as $L + S + C$.

Di-tri and Poly-meric series.—When such terms occur twice, thrice, or many times.

Homo-meric series.—When the successive terms are similarly composed.

Hetero-meric series.—When these are not similarly composed, as $(L + S + C) + (S + L + C) + (C + S + L.)$

Mono-di-tri-poly-nomial terms.—Applied to the number of substances in a term.

Thus the Bolland rocks consist of gritstone, shale, and limestone in one succession. They constitute a trinomial term or monomeric series, and may be thus expressed, $(G + S + L.)$

The Yoredale rocks consist of gritstone, shale, limestone, gritstone, coal, shale, limestone, shale, limestone, in many repetitions. They constitute a hetero-polymeric series.

The following is the succession of beds in the Glory mine, Grassington.

		Ft.	In
Plates above the bearing grit	Plate	5	0
	Top grit and thin plate	30	0
	Plate	1	0
	'*Bearing grit*,' sometimes (60 ft.)	96	0
Black beds, chert, &c.	*Black beds* intermixed with 'famp' and nodules of chert	6	0
	Blue limestone, the veins break through this in joints and threads	9	0
	'Croyl' or indurated clay with shells ...	1	3
Lower limestone	'Pipe-stopper' (crinoidal) limestone	36	0
	Black limestone with water	9	0
	White limestone	35	0
	Stone Plate	9	0
	Limestone not penetrated	60	0

The black beds in this section correspond to the dark laminated limestones previously described, which overlay the lower limestones in Ribblesdale, at Skipton, &c.

In Nidderdale the series greatly resembles that of Grassington.

Nidderdale.—Taking our station at Lofthouse, we find the lower scar limestone mass, cut into both by the Nid and a branch of nearly equal importance, called Steen beck. Passing up the Nid, the limestone is seen covered by four feet six inches of shale, with thin argillaceous limestone in the upper part, then six feet of unevenly bedded blue limestone, then a bed of plate, fourteen inches, on which is a 'famp' bed, (indurated wavy calcareous shale) and upon all, five feet of black compact laminated limestone. Some plate comes on, and then for half a mile further the river runs in a solid coarse pebbly grit rock,—and above this for a vast height is a succession of thick sandstones, and shales, with COAL. Further up the valley, the great limestone rises to some

height, and, after it is thrown down by a fault, pebbly grits appear in the river again. Higher, the Nid is found flowing in the same black cherty limestones and plates as those which cover the great limestone at Lofthouse, about ten feet of limestone resting on twenty feet of plate. Above on each side, toward Middlesmoor and toward Little Whernside, are enormously thick shales, (plates), surmounted by flagstones and shale, with COAL, and a coarse grit rock above. Still higher are more shales and grits for a great height. In Ramsgill, below Lofthouse, the lower limestone is covered by alternating plates, cherts, and limestones, above five fathoms, and on these lies a grit rock, eight fathoms thick, (with coal).

We have, therefore, in general terms:

Above the bearing grit ...	Plates, grits, and coal.
Bearing grit and coal ...	48 feet and more.

		Ft.	In.
Black limestone group	Plate		
	Black compact limestone	5	0
	Famp bed (platy)	1	6
	Plate	1	2
	Blue limestone	6	0
	Plate	4	6
Lower limestone series	Coral bed (Cyathophyllum)	2	0
	Shale and crinoidea	0	0
	Gray limestone	15	0

Passing now to the left bank of Wharfedale, we find extremely satisfactory sections under Great Whernside, so situated with reference one to another, as to permit us to see perfectly the nature of the change from the southern to the northern type of beds. In a small glen descending by a mine from Great Whernside, the passage from the limestone to the superior gritstones is thus observed:—

		Ft.	In.
	Plates and grits above the bearing grit:		
100 ft.	Bearing grit, the upper beds flaggy	100	0
277 ft. Upper limestone group	Plate	84	0
	Sharp hard limestone in nodular beds ...	6	0
	Parting of plate		
	Light coloured limestone	9	0
	Parting of plate		
	Limestone, light coloured	36	0
	Parting of plate		
	Limestone, light coloured	60	0
	Plate	4	6
	Limestone, dark coloured	78	0
	Limestone, with some gritstones and plates	210	0

Passing from this glen head to the north, we come to another branch of the same stream, where we have a very similar section. But further on to the north, from this point to Parkhead, the summit of the Coverdale road, we find a limestone gradually growing more and more apparent, 'putting in,' as the miners say, between the bearing grit and the subjacent plate; it crosses the Coverdale road, occupies a large green area on the summit, ranges down both sides of Coverdale, and along both sides of Wharfedale, above Starbottom, Buckden, &c. West of the Coverdale road, this limestone thickens, and the interval between the bearing grit and the great lower limestone scars continually augments, as the following measured sections will prove,—(*Outline, No.* 1.)

1. West of the Coverdale road, a quarter of a mile:

	Bearing grit and coal:	
Upper limestone group	Limestone of Parkhead ...	30 to 40 feet
	Micaceous sandstone ...	
	Plate and ironstone ...	120
	Chert beds	
	Plate, thin	
	Limestone, shelly and crinoidal	
	Plate, thin	
	Limestone	

2. Above Starbottom :

100 ft. Bearing grit and coal.

Upper limestone series, 510 ft.	Parkhead limestone	30 feet.
	Thin micaceous sandstone ...	80
	Plate	
	Limestone	20 feet ?
	Grits and plates	130
	Thick limestone	50
	Thin flagstone	50
	Thick plate	
	Limestone	80
	Thin gritstone, Plate ...	
	Limestone	
	Parting	70
	Limestone	
	Parting	
	Black limestone	
Lower limestone scars		500

3. Passing on to the head of Bishopdale, we have

Bearing grits, coal, &c.

Chert series	Plate		25
	Little limestone		
	Black and gray chert		
	Plates		
Upper Limestone series	Parkhead (here called 'main') limestone and chert		60
	Flags and plate		100
	Underset limestone with chert on it		60 (It grows thinner towards the N.)
	Plate	60	250
	Grit	100	
	Plate	90	
	Limestone		40
	Plates and grits		100
	Limestone		
	Plates, grits, &c.		
	Limestone		
	Plates and grits		

4. If now we turn to Coverdale, we shall find the Parkhead limestone universally exhibited in its whole length, always *thinnest on the the south-east side;* the underset limestone rather unequally developed, and the beds below subject to much variation.

The principles of the variation from the southern to the northern type in this region, are thus clearly unfolded.

1. The great limestone series, which in Greenhow hill is one mass, admits between some of its upper members partings which are thin at Grassington and Kettlewell, but toward the west, north-west, and north, augment in thickness, and assume new characters.

2. There is a new group of limestone beds introduced in the upper part of the series, (the Parkhead limestones) which augment in thickness toward the north-west.

3. This method of variation may be expressed in a diagram. *(See Diagram, No. 9.)*

THE NORTHERN SERIES.

Lower Limestone Group.

The lower part of the limestone formation, subject to less variation than the upper, fills Kettlewell dale, from Buckden downwards, turns up Litton dale, almost to its source, covers all the wide plateau of Hardflask, and forms the general base of Fountain's fell, Coska and Penyghent; thus uniting Wharfedale and Ribblesdale. The southern boundary of this great area passes along a line of dislocation from Skythorn to Malham, and, bending to the north round Ryeloaf, is continued to Settle. Its lofty escarpments then turn to overhang the Ribble, as far as Stainforth, where the slate ranges make a deep indentation. Beyond, it again resumes its parallelism to the Ribble, and, about two or three miles above Horton, fills the whole valley. Its widening surfaces now extend to the south and the west, so as

to present a great undulated floor of bare limestone rocks, around the cone and slopes of Ingleborough, bordering the valleys in which are the villages of Wharfe and Clapham, filling the upper part and bordering the lower part of Ingletondale, with magnificent and continuous scars. An equally striking succession of precipices appears in Ingleton fells, and Kingsdale, and sweeps round the mountain of Graygarth. A southern range of patches of limestone is traced by Giggleswick scar, Feizer hill, Austwick, Clapham, Newby, and Ingleton, mostly dipping steeply to the south.

Throughout this large area, the limestone rock is nearly undivided by shales or sandstones, and presents one vast calcareous mass, four or five hundred feet thick; sometimes, as in Moughton scar, and on Ingleton fells, piled into magnificent level ranges of precipices, resting on inclined grauwacke. The stone is mostly of a light gray or blue colour; much of it is crinoidal, some is compact. A tendency to vertical fissures is frequent, especially in the thicker masses, so as to give it the aspect of prismatic structure, and confuse the stratification. The lower beds (generally so full of small or large grauwacke fragments, as to be a real limestone conglomerate), are in this respect an exception, for they have little of that vertical fissuring; but on the contrary, are remarkable for the exceeding magnitude of their masses, and the numerous horizontal weatherslits which indicate the unequal composition of the rock. This latter circumstance is well seen in Ingleborough, and still better in Kingsdale, at a waterfall, which shews the lowest limestone beds resting on grauwacke.

The Western Border of Yorkshire.—From Graygarth fell the great limestone escarpment turns round to the north, resting on slate rocks, and shews fine caverns and fissures in its narrow range along the upper part of Leck beck. Confined to an equally narrow course, it shews itself in a dislocated condition along the line of the Penine fault, in the upper part of Barbon beck; between the slate rocks of Barbon and Middleton fell, and the shales, gritstones, and thin limestones of the County stone and Crag. Thus it reaches Denttdale, which it crosses,

and, still continuing in a narrow course, and highly inclined position, passes the end of Rysel fell, crosses Garsdale, and forms the western base of Bar fell, (Bow fell on many maps), and Wild Boar fell. Here a branch of the limestone proceeds to the westward, to encircle the northern boundary of the Cumbrian slates; but the main escarpment turns to the north-east, crossing the valley of the Eden below Pendragon castle, in nearly vertical strata, and proceeds through a country full of dislocations, towards Brough. The numerous and intricate disturbances of the region between Swaledale head and Brough, produce a general depression of the beds, and partially obliterate the grand features of the lower scar limestone; but, beyond Brough its mighty walls of bare gray rocks again encircle the hill breasts, and, with various projections and recesses, continue to characterize the Penine escarpment, beneath Mickle fell, Scordale head, and Cross fell. From this point to the northern termination of that range of hills, the divided lower scar limestones grow less conspicuous, and they are of small importance in the Northumberland moors.

Interior Dales.—The long limestone escarpment just described, from Ribblesdale to Lunesdale, and from Graygarth to Brampton, is only the edge of a vast floor of rock, which underlays the whole of the elevated region from Craven and Wharfedale to the great valley of the Tyne. Sloping to the eastward from the Penine chain, it is for the most part deeply buried beneath hills of the superincumbent strata;—but every deep valley of the interior, in some part of its course, is excavated into this rock, or approaches very near to its surface. The northern valleys of Tynedale, Weardale, Teesdale, and Swaledale, and the western dales of Dent and Garsdale, appear in general only to reach its upper surface; but in Yoredale and Nidderdale, as well as in Wharfedale, Airedale, and Ribblesdale, it makes a prominent feature.

General Remarks.—In its southern escarpments along Wharfedale, and under Ingleborough, the lower limestone is one great calcareous mass, with hardly any traces of argillaceous or sandy alternations; a

character corresponding with the well-known sections of Derbyshire; but in tracing it northwards we find the type changed, and the simple calcareous series varied with interpolations of other rocks. On the northern border of the lake district, its divided lower members alternate with red sandstones and clays,—in all the escarpments north of Brough its upper beds form the predominant parts of a compound group, with sandstones, shales, (plates), and coal; and as we proceed through Northumberland these new terms of the series augment in thickness, predominate over the diminished and deteriorated limestones, and change the aspect of the region, from the green verdure and dry rock of limestone, into the brown heath and wet surfaces of a poor tract of coal measures. The same variations of type, operating in the same directions, are traceable in the interior of the district, as far as the upper parts of the rock are concerned. In Nidderdale the great mass of limestone is covered by black shales, thin black limestones, and cherts, of the Craven series. In the upper ends of Ribblesdale and Dentdale, and generally around Wharnside, the broad upper layers of the limestone alternate with shales. In Yoredale these shales thicken so as to be recognizable beds, (Askrigg, Aysgarth,) and to separate the calcareous layers called the Gale limestone in Wensleydale, and the Tyne bottom limestone in Aldstone moor.

In this progressive change of character to the northward, we lose by degrees the distinction of lower scar limestone, and it becomes not only difficult to draw the line for its upper boundary, but doubtful whether it is proper to make such an attempt. In the northern parts of Northumberland it appears neither desirable nor possible to separate the lower from the similar middle and upper calcareo-carboniferous groups; and in the same country the alternations of the lower beds, with red sandstones, serve to prove how very imperfect would be our views of the contemporaneous physical processes in different parts of the ancient sea, if founded on merely local (however well observed) phenomena. In all the vast thickness of strata, which for distinction we break into systems and consider in sections,

there is but one series of periodically and locally variable mineral terms, but one vast successon of organic forms—suited to the successive conditions of the sea, the land, and the air.

NORTHERN TYPE.

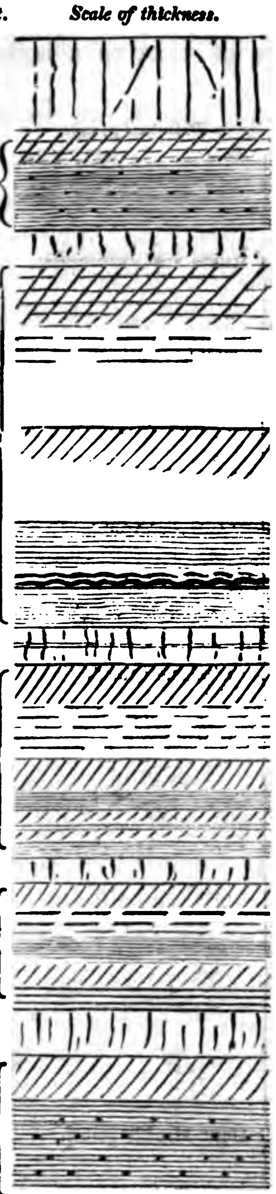
Upper Limestone Series.

The most general character of the lower limestone series is simplicity, but of this upper series, complexity. As in the case of the lower scar limestone, the complexity of the formation augments toward the north. The southern series (Craven) consists almost entirely of argillaceous laminated rocks, locally changing to limestone and chert, generally productive of ironstone, and containing marine exuviæ; the northern type (Teesdale) consists of the same argillaceous basis, (less calcareous and of a coarser grain), with the addition of many layers of sandstone, distinct beds of limestone, thin coal seams, and land plants. In the intermediate districts the coal vanishes, the limestones are reduced to a small thickness, the sandstones become interlaminated with the shales, and the observer feels himself to be in possession of the key of the system of variation.

On the one side, (the northern and western), are the variable effects of inundations from the land, and the inconstant movements near the shores of the sea; on the other, more continual and uniform depositions beneath deeper and more tranquil waters. On this distinction of littoral and oceanic deposits, which is found with *the same geographical relations* in the oolitic series of the North of England, (see the first Volume of this Work, and Encyclop. Metrop. Article, Geology), appears to me to depend the solution of many of the *problems of difference* between contemporaneous deposits, which are beginning to occupy the attention of geologists. It is by this mode of surveying that we may hope to arrive at a knowledge of the ancient Hydrography of the globe.

We shall choose, as a general standard of reference for this complex series of rocks, that district where this character of *complexity*

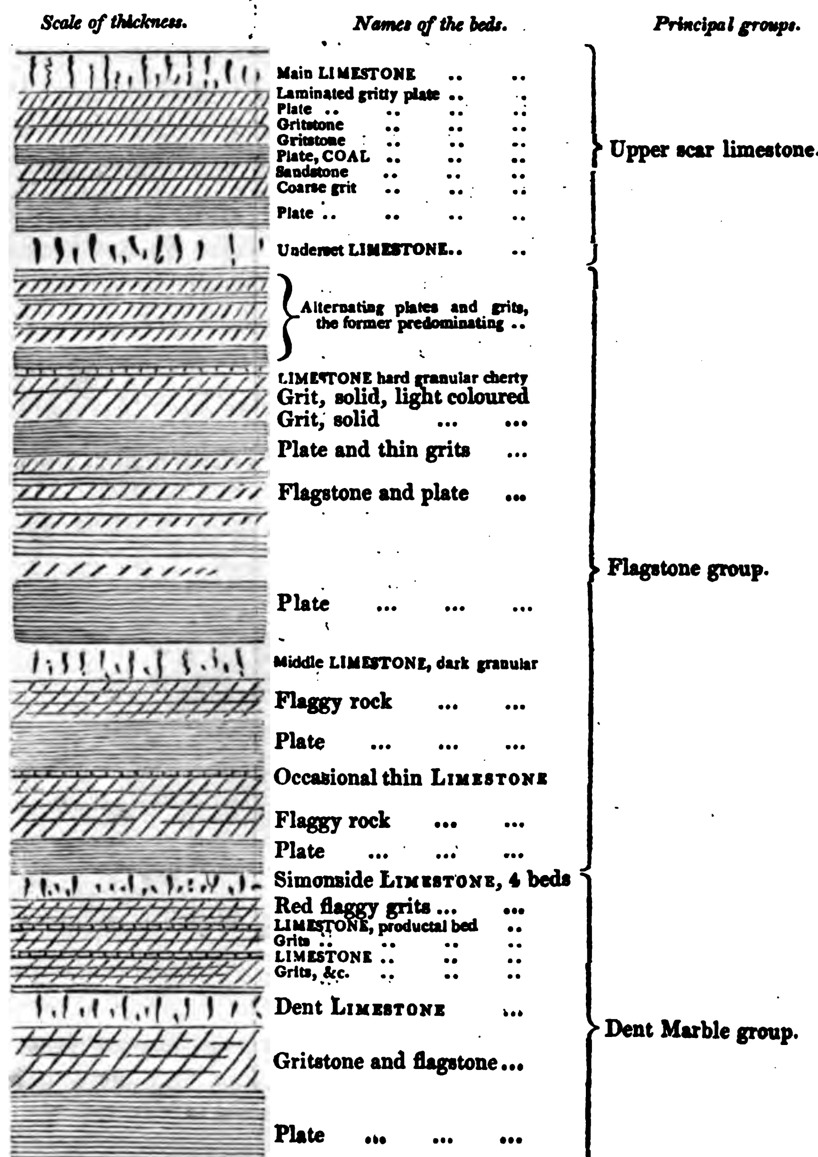
is the greatest. The upper end of Wensleydale is therefore adopted. The total thickness of the upper limestone series in this situation is about one thousand feet, and it consists of the following groups:—constituting what I term the YOREDALE SERIES.



Feet.	*Names of beds.*	*Principal groups.*
70	Main LIMESTONE ...	Cam or upper scar limestones.
80	Laminated grit ...	
	Coal of Cotter fell ...	
	Plate and some ironstone	
30	Underset LIMESTONE	
350	Laminated grit ...	Hawes flagstone group.
	Flagstone of Cotter fell ...	
	Plates and grits ...	
	Strong gritstone ...	
	Plates and grits ...	
	Impure productal LIMESTONE	
	Coal of Lund's thorn ...	
30	Middle LIMESTONE ...	
150	Strong gritstone	
	Flagstone beds of Hawes	
	Gritstone of Millgill force	
	Laminated grits and plates	
20	Simonside LIMESTONE ..	Black limestone group.
100	Flagstone of West Witton	
	Plate	
	Grit	
	Plate	
40	Hardrow LIMESTONE ...	
100	Gritstone	
	Plate and ironstone of Gale	

Lower SCAR LIMESTONE SERIES, of which 240 feet are exposed in Wensleydale.

General view of Wharnside.—From three several examinations on the eastern, south-western, and northern faces of Wharnside, all continued from the lower limestone to the summit of the main limestone, the following complete view of the composition of the Yoredale series in that mountain has been constructed. Its accordance with the Hawes section is very satisfactory, and justifies the use of that as a common standard of reference.



Having thus obtained from numerous local sections a clear and certain general standard of the whole Yoredale series, and verified it by a rigorous comparison with the equally complete section of Wharnside, it remains to trace the variations to which this interesting group of rocks is liable in its extension to the east and west in Wensleydale, and to the north and south of the valley.

West of Hawes.—In passing westward from Hawes to Dentdale, there is little variation of the terms of the Yoredale series, except that flagstone is dug, not only between the underset and Simonside limestones, but also (at Stonehouse in Dentdale,) below the Hardrow limestone. In other respects and viewed generally, the slopes of Widdale fell and Snays fell, on each side of the Widdale beck, give the same section as Bear's Head or Weather fell, and differ in no sensible degree from that of Wharnside.

Neither is any great variation perceived in passing by the lower summit of drainage from Wensleydale to Garsdale. The ascent from Hawes leads successively over the Hardrow, Simonside, and middle limestone, and the same are found in deseending Garsdale. At the summit of drainage, indeed, a coal seam has been worked above the middle limestone, and this is the only circumstance in which the valley of Helbeck Lund differs from the standard type of Wensleydale. The same double line of the upper limestone scars, a similar succession of flagstones and plates, are seen on the sides of Swarth fell and Cotter fell. But in Bar fell, for its whole length against Garsdale, there is a difficulty in tracing more than one of the upper limestones, and this, which produces the celebrated crinoidal marble of Garsdale, seems about thirty feet thick, being covered above by the grit and coal series of Penyghent. The middle limestone, and subjacent sandstone, and perhaps some of the lower Yoredale limestones, are seen in several parts of the stream; flagstones, having the surfaces covered by carbonaceous matter, and marked by vermicular and phytoid (jointed) ramifications, are dug in Rysel,—only one limestone being traced above them. These correspond to the flagstone quarries in Helbeck Lund, at the head of

Kingsdale, and in Stag fell, and Cotter fell, north and north-west of Hawes.

East of Hawes.—In its eastward extension the Yoredale series preserves a certain uniformity of character through the whole extent of Wensleydale. The lower scar limestones continue to occupy the bottom of this great hollow of denudation, as far as Redmire, being covered on both sides by a system of five considerable limestones, with alternating shales and flagstones, which are exposed in the front of Addleburgh and Penhill and on the sides of Simmer water, Bishopdale, Waldendale, and Coverdale, as well as in Millgill, and the mountains over Askrigg, Bolton castle, and Wensley.

The summit of Addleburgh is formed of the underset limestone, here thicker than usual, and the Hardrow limestone appears in the fine terrace of Thornton and Wotton, which corresponds to one equally grand on the north of the valley, extending, with some interruptions, from Hardrow to Bolton park. The whole series may be thus stated.

	Feet.		
	50	Underset limestone in a mural precipice:	
Flagstone group	280	Flagstone series	Gritstone and plates 250.
			Limestone, impure, with productæ, &c.
			Plates, &c.
	40	Middle limestone in a long double scar.	
	150	Gritstones and plates.	
Black limestone group	20	Simonside limestone.	
	100	Plates and grits.	
	30	Hardrow limestone.	
	100	Grit on	
		Plate.	
	770	Feet.	

In connection with this we may present a section of the lower beds in Millgill, near Askrigg, (taken in 1825).

	Feet.
Thick grits and plates of Upper Millgill force ..	80
Limestone of Simonside	30
Alternating grits and plates, with three thin beds of dark limestone containing caryophyllia	60
Limestone of Hardrow, forming the edge of Lower Millgill force	40
Gritstone	110

Limestone belonging to the lower system.

In Pen hill we have the whole series about seven hundred feet thick, and notice in succession below the millstone grit, and upper flagstone, and coal,

The little limestone.
Black chert and plates.

Upper limestone { The main limestone reduced in thickness.
Plates, grits, and coal.
The underset limestone. }

Flagstone group { Grits and plates of considerable thickness, but not so thick as above Hawes.
The middle limestone here of considerable thickness.
Grits and plates. }

Black limestone group { The Simonside limestone.
Flagstone and plate.
The Hardrow scar limestone, which ranges from Bishopdale by West Witton and enters the Yore opposite Bolton hall.
Grits and plates resting on }

The lower scar limestone divided by several plate beds.

It is evident, therefore, that in an east and west direction the Yoredale series retains so much of a definite character as to afford an ample general standard, to which all the variations on the south and north may be very conveniently compared. In general it is evident that the limestones approximate continually nearer together as we proceed eastward, the intermediate beds growing thinner.

Coverdale.—Descending from Pen hill in a south-eastward direction to Melmerby, we cross the grit of the summit, and below it a series of flagstones, plates, and coal, dipping E. About six hundred feet below the summit, Melmerby Beck falls among beds of chert (partially decomposed to rottenstone) about twelve feet thick; a quarter of a mile to the south, and about six hundred and fifty feet below the summit, is a remarkable quarry of main limestone, resting on twenty-five feet of yellow laminated grits, and seventy-five feet of plate. The limestone is in a singular condition, and as full of vertical and inclined joints, as greenstone rocks often are. The stone is brown and ochry (as usual where it is changing to chert) and crinoidal. It ranges obscurely by some green banks to the north, and holds an indistinct course along the high ground to the head of the dale. Below the plate lies a flag-like bed of impure crinoidal limestone, then twenty feet of solid grit-stone, holding spirifera; thin plates and grits follow, and next, about sixteen feet of yellowish gray crinoidal limestone. In the course of two hundred and eighty feet farther descent, the stream crosses other limestones, but the section is not satisfactory.

At its junction with the river Cover, limestone in thick beds appears and ranges up Scrafton Beck for one hundred and thirty feet; shewing prismatic structure on a grand scale, especially at the great precipice and remarkable cascade which terminate the cliffs. Beyond, limestone continues in the stream to Great Scrafton, and the total thickness here exposed is taken at one hundred and fifty or one hundred and sixty feet. It is covered by plate. The same blue and gray limestone is seen from Scrafton to Coverdale Abbey, and it is the lowest rock in that part of the valley. In Caldbergh Beck about one hundred feet of this rock is exposed *below* the road, and *above*, it supports a series of alternating grits and plates about thirty feet thick, but, as there is a dislocation here, this is probably much too low a measure; the real thickness is doubtless above one hundred feet. On these rests a solid, gray limestone rock, very crinoidal and full of chert nodules. (The joints expand laterally into oval cavities, evidently excavated by water and full of clay.) This limestone is about twenty-five feet thick. Hard

shale beds come on above; then grits and plates; then one solid bed of limestone under beds of red, and gray, and dark chert, twenty-five feet in thickness. This chert is often rotten in the central and other parts and dark, smoky gray, striped, dendritical, or purplish within, with hardly any organic remains. It decomposes into a kind of 'rottenstone.' At the top, chert nodules are interspersed. Shales and grits come on above, but no other distinct limestone appears.

This upper limestone is traceable along an escarpment generally near to the road from Coverdale to East Witton, being above the road as far as Braithwaite hall, but below the road (which runs in places on its terrace surface) from thence to East Witton. Plates appear below its range, and shales, cherts, and grits above. About fifteen feet of limestone are seen, and water breaks out at this level. In East Witton it was sunk through about seven yards in thickness. Plates and grits below.

Near East Witton it is much quarried, and appears wholly crinoidal, and full of undulated beds and nodules of chert also crinoidal, and contains productæ and other fossils. The chert is gray (rarely black), often decomposing to brown rottenstone and then discloses multitudes of crinoidal joints. Above is a remarkable parallel bank, reminding us of that formed by the black chert beds of Leyburn and Pen hill.

This cherty and crinoidal limestone is the only representative of the Cam or upper scar group, and the occurrence of the variously cherty series above, (as in the north of Wensleydale, and in Swaledale generally, and on the opposite slopes of Pen hill,) and the laminated grits and plates below, leads me to refer it to the main lime; I do so with the more confidence, because in the north-west side of Coverdale both the main lime and underset lime exist together; the latter being certainly continuous with the Parkhead limestone, at the head of the valley, and being much analogous to this limestone of East Witton and Caldbergh. In its course up the valley, on the south-east side, this limestone is not very conspicuous, except in the stream near Hindlethwaite, which

descends from the moors in a deep ravine, and other small becks, but it is nowhere deficient, and indeed can be traced from East Witton to Parkhead, except about Great Scrafton.

In the middle of Coverdale the blue limestone series rises above the river, and exposes at Gammersgill a flagstone series beneath. The extensive quarries here produce excellent stone, with carbonaceous surfaces, which are often covered with nodules, and vermicular, and ramified markings.

The sections at the head of Coverdale are exceedingly interesting with reference to the upper crinoidal limestones, whose diminished and debased character is by them found to prevail through the whole of this valley, especially on the S. E. side.

The main lime is seen distinctly encircling the head of the dale in a belt of rocks, and is cut through by the streams which enter the left bank of the Cover. On the opposite side, beneath Great Whernside, this rock is much thinner, but it no where really vanishes from the section. It is usually crinoidal in texture, with undulated nodules of gray chert.

On the left (north-west) bank we have, beneath grits and shales,

Feet.	
50 or 60 ?	of the main or Parkhead limestone.
100	Principally plate.
15	Limestone, gray crinoidal.
40	Plates and flaggy grits, with tessular ironstone bands.
	Limestone blue, hard, jointed.

On the right side of Coverdale, a stream from between Great and Little Whernside, gives this section.

		Feet.	
	Bearing grit ...	100	
Upper limestone	Main or Parkhead lime ...	20	with nodules and bands of chert.
	Plate and ironstone ...	90	
	Underset lime	10	

Flagstone series	Flagstone ... Tessular, irony hasle Plate ...	60	
	Limestone ... Gritstone ...	20	
	Plate...	20	
	Limestone	10	
	Plate, rich in fossils ...	6	
	Limestone in many beds with lithodendra on the top, and large productæ in all the lower beds	50 and more	This is supposed to be Hardrow fall limestone.

Still nearer the summit and on the right side of Coverdale, a little stream, descending from a surface of pebbly and flaggy grits, and shales, (five hundred feet below Great Whernside) exposes the following beds:

Feet.	
70	Gritstone and flaggy beds.
(20)	Parkhead limestone overlapped by the grit at the stream, but appearing on each side.
100	Dark plate.
15	Limestone 'underset' (in the state of 'dun' lime).
50	Flagstone and plate.
28	Limestone.
	Plate, rich in organic remains.

South-eastern limits of the Yoredale Series.—Comparing these sections in Coverdale with those formerly given in the adjacent parts of Kettlewell dale, (pp. 30, 31,) it will be seen that both the main lime and underset lime (together making the Cam group) become gradually but completely extinguished on the west front of Great Whernside; not because of any dislocation, but as a law of their original deposition. These limestones have no existence farther to the south-east than the line indicated (p. 19,) as the southern boundary of the Yoredale series. It will also be seen that the gritstones, and plates, and coal, which essentially characterize the Yoredale series, terminate almost completely on the same boundary line as the Cam group; and comparison of the sections of Great Whernside, Parkhead, Starbottom, and Bishopdale head given in pp.

30, 31, with the Hawes section p. 38, will prove in addition that the development of these grits, and shales, and coal, is proportioned to that of the Cam limestone, so that the deposition of both groups may be referred to the same agencies. The geographical *origin* of these agencies may be satisfactorily inferred from the local amount of their effects; the *nature* of the agencies is indicated by the mineral *nature* of the deposits; and from the whole combined we may believe that the line through Jervaux abbey, Kettlewell, Ryeloaf, and Lancaster, divides the oceanic from the littoral portion of the great mountain limestone deposits.

Parting from below Great Whernside, as a centre, we find that along the whole length of Coverdale, stretching fifteen miles to the *north-east, parallel to the coast line*, the thickness of plates and grits above the middle lime, augments from eighty to only one hundred and fifty feet;—in an *easterly* direction it is diminished to thirty, and in a southerly and south-easterly direction appears to vanish altogether. In like manner all the flagstones and plates under the middle limestone, in Great Whernside, are included in a space of one hundred and fifty feet: this space augments on the north by east to four hundred and eighty feet, on the north-west (Hawes) *or proceeding directly toward the ancient shore*, to seven hundred and eighty feet, on the west (Penyghent) to three hundred feet; but on the east, south-east, and south *proceeding toward the deep sea*, it is reduced to nothing.

The influence of land inundations, and littoral movements is greatest toward the north-west, where the slate ranges of Cumbria had been uplifted; the purely oceanic character of the limestones is greatest toward the south-east, where land was in that æra very distant.

South-Western Districts of the Yoredale Series.—Proceeding to the S. W. for the purpose of connecting the general base of the series, in Wensleydale, with that in Ribblesdale, and passing over the intermediate mountains by Weather fell, (or Bear fell), Dod fell, and Cam fell, we obtain the following results. The surface of the lower limestones rises from Wensleydale to Ribble head, nearly two hundred feet; the Yoredale series is about one thousand feet thick; in

passing from Weather fell to the eastern end of Cam fell, the interval between the main and underset limestones, (only forty feet in Weather fell), continually diminishes; the underset limestone, which is fifty feet thick over Wensleydale, becomes much thinner, and finally the two rocks appear united in one crinoidal limestone in the southern front of Cam fell, over a great mass of flagstones and plates; detached masses of the millstone grit series lie over this limestone in Weather fell and Dod fell). Crossing the rather obscure country of plates, grits, and limestones, between Cam fell and Ribble head, we find the same series in Ingleborough, composed in like manner, of about five hundred feet of plates and laminated grits, with limestones and plates at the bottom; on this rests *crinoidal limestone rock*, thirty feet thick, covered by alternating grits and plates; and the whole is crowned by a pebbly millstone grit. This, which we shall in future designate as the Ingleborough grit, is the same as that already noticed above Kettlewell and in Nidderdale. In Penyghent also the main limestone occurs under a cover of Ingleborough grit, inclosed in shales, and flagstones with COAL. There is no underset limestone.

The whole series, above five hundred feet thick, was thus observed, (1833).

	Feet.	
	8	Little limestone.
	10	Plate.
	60	Cam limestone.
225	15	Gritstone laminated.
	60	Plates.
	150	Gritstone and flagstone. Thick plate?
	20	Limestone.
92	60	Plate.
	6	Limestone, with one bed of fossiliferous plate.
	6	Plate.
	10	Alternations of sandstone and plate (crinoidea at bottom).
	10	Plate.
	20	Limestone (Simonside), in great beds, blue below, gray above, small crinoidal.

	Feet.	
62	20	Gritstone (and plate).
	3	Limestone (sandy, hard blue).
	3	Plate.
	6	Hard micaceous grit.
	30	Plate.
40		Hardrow scar limestone, with lithodendra, and turbinolia, and productæ.
		Thin plates.
		Limestone beds.
		Thin plate with crinoidea.
		Limestone in the valley between Fountains and Penyghent.

South of Penyghent, we have the Hardrow beds well exhibited.

a. Chert caryophyllia in black limestone, loose corals in the soil, the limestone having decomposed.
b. Black limestone with productæ.
c. Shale.
d. Dark rough limestone.
e. Ditto.
f. Gray limestone. In the shales are spiriferæ, crinoidea, orthoceras.

In Fountains fell, the upper limestone resembles that in Penyghent, but is not so thick, there is no underset limestone. It is covered by the Ingleborough grit, alternating with shales and COAL.

Feet.	
10.	Light coloured crinoidal limestone.
55.	Flagstones.
	Shale.
45.	Limestone, dark and gray with chert in beds and nodules, few fossils
100.	Thick shale, near the middle are two layers of sandstone.
	In the shales below, abundance of ironstones, in one of which ammonites were found.
	Near the bottom a thin layer of cherty rottenstone.

Feet.	
20.	Blue crinoidal limestone.
35.	Shale.
15.	Limestone, light coloured.
50.	Gritstone, thin.
	Shale.
90.	Calcareous layers with shells and turbinolia.
	Thick shales.
	Two or three beds of blue limestone in shale.
160.	Strong angular sandstone.
	Limestone.
	Limestones, &c.
	Limestone under fossiliferous plates.

Northern districts of the Yoredale Series.—We may now proceed to trace the character of the Yoredale series in the country farther north. Swaledale, which runs from west to east parallel to Wensleydale, Arkendale which runs in a south-east direction and enters the left bank of the Swale, the vale of the Greta, Lunedale, and Teesdale, with the escarpments of the Penine chain, will afford us sufficient data for this research. It must, however, be observed, that not one of the valleys named, nor any other lying to the north of Wensleydale, shews so completely as that the lower scar limestones which are the general base of the system.

Swaledale.—This great valley is remarkable for commencing at a very high mountain pass, in beds above the whole of the Yoredale limestones; it then excavates its passage through the main, underset, middle, Simonside, and Hardrow limestones, and again crosses these rocks as they necessarily sink eastward faster than the stream. The lower limestones are best seen about Muker, the upper belt is every where conspicuous. In a general sense, and as compared with Yoredale, Swaledale may be said to be in a depression of the strata. It is full of dislocations. Five lines of section have been attended to in connecting the Yoredale and Swaledale series: the first is from Hawes to Muker, over Stag fell, and down Cliff gill; the second from Askrigg to Muker;

the third from Redmire by Bolton castle to Reeth; the fourth from Leyburn to Reeth; the fifth from Leyburn to Richmond.

On ascending from Hawes to Stag fell and Lovely seat, we have the Yoredale section well exhibited, except for a part between the Simonside and underset limestones; the middle limestone is not clearly seen in this thick flagstone series.

	Feet.		
Millstone grit series, 535		Various grits, and shales, and COAL.	
		Pebbly gritstone (millstone grit of Ingleborough top).	
		Shales.	
		Black chert on one bed of limestone	Chert group.
		Brown rotten chert ...	
		Plate	
		Limestone	
		Plate	
Cam limestones	75	Twelve fathom, or main limestone.	
	40 ?	Gritstone. Flagstone. Plate.	
	50	Limestone called underset in Swaledale (here thicker than usual, having chert on the top of it).	
Hawes flagstones 475		Block gritstone / Flagstones ...	153 feet.
		Thick plates and grits ...	250
		Solid sandstones / Plate ...	70
Hardrow limestones	10	Limestone (called the Simonside limestone).	
	70	Gritstone. Plate. Grit. Thin plate.	
	30	Limestone (of Hardrow).	
	110	Gritstone 30 feet. Plate ... 80	
		Limestone of the lower scar series.	
	1396		

The descent of Cliff gill gives a satisfactory section for Swaledale,

Feet.		
662	Upper grits and coal shales. Ingleborough grit, &c. Chert group	Black chert. Limestone. Brown rotten chert. Plate. Limestone. Plate.
82	Main limestone.	
40	Grits and plates ...	Strong grit, Flagstone 15 Plates 25
54	Underset limestone ...	Chert at top. Limestone.
197	Grits and plates (called 27 fathom Grits and plates) ...	Block grit, 12. Flagstone and plate.
15+	Limestone (middle limestone).	
70	Plates and grits ...	Plates, &c. 60 Gritstone 8 Plate ... 8
75	Limestones, ... Grits and plates ...	Limestone ... ... 4 Plate and grits, Grits 50 limestone beds: Limestone 2, Plate 12, Limestone 6
54	Grits and shales.	
20	Limestone, dark.	
70	Flagstones and plate ...	Plate, thin. Solid and thin grits. Plates. Strong gritstone.
1339		

Lowest limestone of Swaledale in the river below Muker.

In proceeding down Swaledale toward Reeth the lower limestones of the Cliff gill section gradually sink below the level of the valley, but so slowly that it is not till we reach Downholme that the scars of the upper limestones come to overhang the river. In crossing over from Askrigg to Muker, the section is very similar to that from Hawes to Muker, excepting that the limestones are nearer together: the road from Wensley by Leyburn to Reeth, or from Redmire by Bolton to Reeth, gives on the south side a deeper view of the Yoredale series than on the Swaledale side, but the upper terms are in accordance. Below Downholme nearly to Richmond, the upper scar limestones appear above an undulated surface or steep cliff, of 'twenty-seven fathom grit and shale:' the same is the case on the north side, where long digitations of the mountains come boldly to the Swale, and on the road down Fremington edge we cross the middle limestone of Cliff gill (here rich in fossils) two hundred feet above the valley. On all the valleys on the north side of Swaledale as far as Stonedale, the upper scar limestones are seen over the grit and shale series, and at Feetham Row and other places the limestones of Cliff gill appear below.

Arkendale.—The same series occurs in Arkendale from Fremington to the termination of the dale in open moorlands beyond Baxton knab; the double scar of upper limestones keeping every where a distinct course along all the edges and across all the gills, (often broken by dislocations), and having below it the grits and plates of the flag-stone series, and above it the same cherty covering as at Leyburn, with the same little limestone, and above that, one or even two other limestones and thin coal seams. This is perfectly seen at Punchard gill, and is known by the section of Old Moulds mine, which will be found in a future page. From the western parts of Swaledale the ascent by Stonesdale to Water crag, and the descent to Arkendale by Punchard gill, afford satisfactory sections of the upper parts of the Yoredale series.

One hundred and fifty feet above Muker, forty feet above the lower limestone in Cliff gill, and twelve hundred feet under the summit

of Water crag, is the top of the underset limestone at Crackpot hall; but at east Stonesdale beck it is three hundred feet above Muker. Chert lies on the top, as usual in Swaledale; sixty feet of plate, flaggy beds, and gritstones succeed, (the upper grit is called underset grit); about eighty feet? of main limestone come above, (here rich in producta gigantea and corals); then plate, lime, chert, plate, chert, and thick plate, for one hundred and twenty feet; eighty feet of gritstone; fifty feet of plate, black gray and reddish cherts, and plates; above are six hundred and sixty feet of plates, gritstones, plates and coal, to the summit of Water crag.

On the east or Punchard gill side, after passing four hundred feet of grits and shales from the summit of Water crag we arrive at the outcrop edge of a coal seam, above a coarse grit; one hundred and seventy feet lower are laminated gray, blue, and spotted chert beds, and cellular chert, lying in shale and yielding fossils; about two hundred and forty feet lower we reach the top of the main limestone; one hundred and ninety feet lower the base of the underset limestone; then follows a succession of gritstones, flagstones, and plates, with one (the middle) limestone to the bottom of Arkendale at Seal's houses, in all two hundred and thirty feet.

Vale of Greta.—In another direction we may rise from Arkendale to the narrow pass of the 'Cross of Greet,' and descend into the vale of Greta and Teesdale, by Hope, Scar gill, and Greta Bridge. This very instructive route gives on the Teesdale slopes exactly the usual terms of the Yoredale series, viz. below the gritstone, and plates, and cherts of the summit of the pass, main limestone, grits and plates, underset limestone, and flagstone series. The latter extends for some length up the Greta above Brignall, yielding very capital stone, and about Rutherford bridge a lower limestone is exposed on the banks of the river. From the Greta the general dip of the country is northward, so that toward Barnard Castle the upper limestones soon sink under plates and gritstones; the main limestone fills the Tees and the Greta about Rokeby; Brignall, and Scar gill

thus occupy nearly the centre of what may be called an immense denudation of the upper part of the Yoredale series. The main limestone, commencing in the Greta above God's bridge, (west of Bowes) extends to the south by a sinuous course along the edge of the moors above Hope, Scar gill, and Barningham, and afterwards by Dalton, Sayles, Ravensworth, Wharleton, and Gilling; it then turns obscurely round a slightly elevated country to Moulton and Middleton Tyas, where it resumes its importance and suddenly ends. From Gilling the northern edge of this denudation passes by Hartforth and Browston bank, to Hutton and the valley of Forcett, and returns to the Tees near Rokeby.

Teesdale.—From Eggleston near Rokeby to a little above Eggleston near Middleton, the Tees runs entirely in plates and grits which lie over the main limestone. It may be considered as crossing a great depression of strata, occupying a broad area between and parallel to the Lune and the Greta, (east by north). This depression is continued into Durham between the Wear and the Tees, as indicated by the westward extension of the lower coal series in Cockfield fell, &c. From Mickleton the limestone country expands over the whole of the north-west angle of Yorkshire, between the Lune, the Tees, and Maisebeck;—but in this part of the country an unexpected and very important rock is interposed amongst the limestones in such masses as to predominate in the general aspect of a large region, and give to upper Teesdale the character of a basaltic formation.

Nearly in the centre of the triangular space between the Tees and the Lune rises the mountain of Mickle fell, probably the loftiest in Yorkshire, but inferior to Cross fell. This mountain is girt by scars of main limestone, bearing toward the western ends two patches of superincumbent grits and shales. The limestone surface is about one thousand five hundred feet above the basaltic rocks at the High force, and about one thousand feet above those at Caldron snout. The following is a section of beds seen between the foot of Caldron force and the limestone summits of Mickle fell.

		Feet.
Main limestone	... ...	60
Traces of underset limestone	...	140 below the summit.
Gritstone edges	... ...	ditto.
Gritstone edges	... ...	420 ditto.
Limestone, dark (12 ft.)	..	645 ditto.
Limestone, blue	... ...	730 ditto.

The descent of the same mountain by the mines toward White force gives additional facts, but complicated dislocations render it difficult to construct a complete series.

			Feet.
	Main limestone of the summit.		
	Underset limestone	... ...	130 below the summit.
	Gritstone	... ...	288 (High Brigstone hazle.)
(This space is too great, there are dislocations passing here.)			
Three yard	Limestone (thin)	... ...	567
	Gritstone	... ...	575
	Limestone, dark (12 ft.)	...	600
	Limestone (6 ft.)	... ...	625 ?
	Limestone (6 ft.)	... ...	645
	Limestone	... ...	708
	Limestone (Tyne bottom L.)	...	858
	Whin sill (basalt.)		

Following a branch of Maize beck to High-cup-nick, we see there on the sides of the pass the Yoredale series above the Whin sill thus exhibited :

Strong grit rocks. Brigstone hazle of Teesdale, (six fathom hazle of Aldstone moor.)
Plates and grits.
Scar limestone.
Alternations of grit and plate.
Limestone.
Alternations of grit and plate.
Tyne bottom limestone.
Alternations of grit, plate, &c.
Whin sill.

Again at Knock Ore gill head,

	Feet.
Strong grit rocks	280
Alternations of plate, grit, limestone, &c.	
Top of Tyne bottom limestone.	

In the branches of Troutbeck the Tyne bottom limestone is covered by shales and limestones, thus:

	Feet.
Scar limestone.	125
Alternations.	
Top of (cockle shell) limestone...	
Alternations	
Broad floors of limestone (Post L.)	
Plate	
Top of Tyne bottom limestone.	

At Middleton,

	Feet.
Main limestone	50
Grit and shale	84
Underset limestone	24
Grit (Nattriss gill hazle) ...	50
Plate...	
Three yard limestone and plate	7
High Brigstone hazle	36

From all these and other data results a general view of the succession of the strata in the vale of Greta and Teesdale below the millstone grit group:

	Feet.
Main limestone	70
Various alternations	80
Underset limestone	24
Various, including one coal seam, one or more limestones, several plates, one or two principal grit rocks, flagstones, &c.	150 to 350
Scar limestone	15 to 40
Various alternations, including a bed of coal, and one or more beds of limestone	125 to 225
Tyne bottom limestone	25 to 50
	489 to 839

This is so nearly in accordance with the section of Aldstone moor, given by Mr. Forster, as to leave no doubt of the continuity of most of the beds of limestone and some of the beds of gritstone.

In Mr. Forster's section of the strata in the mining country of Aldstone moor the same terms are thus found:

	Feet.
Great limestone	63
Various, including a thin limestone ...	101½
Four fathom limestone	24
Various, including two limestones and at the bottom a thick gritstone ..	143½
Scar limestone	30
Various, including a bed of coal, and two thin limestones	130
Tyne bottom limestone	24
	515
Whetstone bed.	
Whin sill.	

North-west of the High force, between Ettersgill beck and Langdon beck, on the downcast side of Burtreeford dyke, the Yoredale series may be examined in an escarpment not above three hundred and sixty feet in height, coal, shales, and grits coming on above, the Whin sill being about eighty feet below. Two sections were taken in different directions. (The beds dip into the hill which considerably reduces their apparent thickness.)

	Feet.		
Top of main limestone.			
Base of ditto	63 below the top.		
Grits and shales.			
Top of underset limestone ...	142		
Top of solid gritstone ...	242		
Top of scar limestone ...	317	and	262
Bottom of ditto?	329	...	274
Shales and grits.			
Hard gritstone		...	322
Top of Tyne bottom limestone	412	...	357
Base of ditto	436	...	381
Top of Whin sill	516	...	461

MILLSTONE GRIT SERIES.

From what has been proved on the subject of the change of type of the lower scar limestones, and the Yoredale rocks, it follows that not only a simple homogeneous series of rocks may be rendered complex by the intervention of other rocks, so as to constitute a binary or triple succession, but also that the corresponding terms of the series are subject to great variation. Thus the main limestone has no existence in the large tract between Coverdale and Wharfedale, the limestones above that of Hardrow scar vary much in regard to thickness and interval. Now of all the strata in the Yoredale series the limestones are by far the most continuous and permanent; had we attempted to construct the diagram of corresponding geological age, in distant parts of Yorkshire, by a comparison of the sandstones and plates, the results would have been almost imaginary; and lines of demarcation in the carboniferous series would have been worse than useless.

The millstone grit series rests upon the Yoredale rocks; but what shall we take as their common boundary?

Both of these groups of rocks consist of limestone, sandstones, shales, ironstones, and thin coal seams; but while limestones abound in the lower group, sandstones predominate in the upper, and limestones become almost obliterated. If we were to proceed upon the principle of including all limestone beds with marine exuviæ in the Yoredale series, we should have the following results. 1. A thickness of grits and shales to the extent of several hundred feet, with only a few yards of limestone, would be ranked with a series eminently calcareous. 2. The distinction for all parts south of the Craven fault and east of Wharfedale and Coverdale, becomes imaginary, or would divide the real millstone grit series into two parts. But, if instead of that arbitrary rule we look at the larger indications of nature, and make our classification fit to the physical aspect of the country and leading members of the groups, we shall include in the millstone grit

and shale series, all the beds which lie above the main or twelve fathom limestone, and which form the high heathy and boggy summits above the green slopes and scars of Yoredale limestone.

It is only by a thorough knowledge of the country occupied by the millstone grit series of rocks, that they can be at all classified and reduced to a general system or type.

THE LOWEST PEBBLY GRIT group known in the whole region south of the Tyne, is found every where almost in contact with the top of the limestone in the districts of Nidderdale, Greenhow hill, and Kettlewell. At Greenhow hill and Grassington its inferiority of position to the bold crag grits of Brimham and Symon's seat is most certain, and the measures which I have taken in the upper and lower parts of Nidderdale, (above Lofthouse, at Brimham, Guise cliff, Darley, &c.) and about Greenhow, justify the assertion that at least seven hundred feet of shales, flagstones, and grit rocks, with one or more seams of coal and cherty beds intervene. Some of these grit rocks are coarse and occasionally pebbly, (above Pately bridge, and above Darley, Blubberhouses, &c.)

One principal mass of the Brimham grits ranges E. N. E. and W. S. W., between the nearly parallel anticlinal elevations of Burnsall and Bolton. Between the Rylstone and Flasby fells, a valley of the subjacent shale passes, and in this tract the thickness of the shales and grits between the Rylstone grit and the limestone is probably not less than that above recorded.

The gritstone of the Strid near Barden tower, is probably the lower millstone grit; I am now disposed to assign the same place to that which appears in the Washbourn river, at Thurscross; it may also be traced above some considerable thickness of shale near Bolton bridge, especially under Gaukhall ridge, being every where eminently pebbly. It is not very distinct beneath the Flasby and Rylstone fells, toward the west.

The fact already established of the attenuation of the whole Yoredale series, in a south-eastward direction, now becomes important. We have seen how the Yoredale rocks were reduced in thickness from Hawes to Great Whernside. As there can be no doubt of the continuity of the upper part of the great limestone masses of Whernside, Lofthouse, and Grassington, we are forced to admit that the pebbly gritstone which lies over the Parkhead limestone at Kettlewell is identical with that of Lofthouse, and this with the lower grits of Greenhow and Grassington. It is already proved to a certainty that the Parkhead limestone is the main or twelve fathom limestone of Swaledale, Yoredale, Wharnside, Ingleborough, and Penyghent. It follows that the pebbly grit (bearing grit) of Nidderdale, like the 'millstone grit' of Ingleborough, is above the main limestone, and far below the 'millstone grit of Brimham.'

What, then, is the relation of the Nidderdale millstone grit to the Ingleborough grit; both being certainly proved to be not far above the main limestone? To those geologists who are not practically versed in the variations of sedimentary rocks, this question may appear of easy solution. It is nevertheless replete with embarrassment. For as all the terms of the Yoredale series, previously discussed, vary with locality, and as all the terms of this millstone grit series, coal, shale, grit, and limestone, are still more variable, and according to different laws, which refer to different local centres, and as finally the Ingleborough grit lies very much in distant outliers, I have hesitated long before fixing my opinion.

Parting from Ingleborough, where this grit forms the very summit of the mountain, we find in Penyghent the very same limestone series surmounted by the same millstone grit, and on this a considerable thickness of shales and grits yielding coal. In Fountains fell also, the same grit occurs, *but thinner*, under the same coal shales and grits as in Penyghent. A similar but less complete section in Coska, conducts us to the ridge between Littondale and Langsterdale, which consists of those grit rocks and shales lying over the main limestone,

which are visible on the other side of the Wharfe in the same relative position as in Fountains fell. Along this line the connection of the Ingleborough and Nidderdale grit appears perfectly clear, the same limestone below, at the same moderate distance, and similar coal workings in connection with the grit. The shales and grits below the main limestone vanish toward the east.

Proceeding from Fountains fell to the south-east, we arrive at the great Craven fault, which embarrasses the inquiry. Yet as in this fell the whole series below the main limestone is greatly diminished from its thickness in Wensleydale, more shaly, less gritty, with thinner and more debased limestones, as also in particular the main limestone seems to lose itself toward the south,—we see how it happens that the series below the Ingleborough gritstone, becomes confounded with that above it; and where it is indistinct, as in the Flasby and Rylstone fells, the whole constitutes the one great shale series of Craven. Rylstone and Brown hill have this grit at or near their summits; it is in greater force about Settle and Giggleswick, underlays the Ingleton and Bentham coal fields, and forms the lower part of the millstone grit rocks of Bolland, Lancaster, Dockray moor, &c., and the crown of Pendle hill and Longridge.

It follows from this view, that in Wharfedale and Nidderdale there is hardly more than a trace of the shales below the main limestone (Craven lower shale;) that in both these valleys the great shales and sandstone series belong to a group above the main limestone; while in all the west of Craven shales occur, which belong both to the series above the main lime and to that below. The north-western parts of the Craven shale belong principally to the lower series, in the south-east parts upper shales and upper grits come on. In the lower shale series only, as at Flasby, in Wyersdale, and elsewhere in Bolland, occur the fossils of the true mountain limestone type, (ammonites, sphæricus, &c.) which at Fountains fell, and near Hawes, lie amongst the Yoredale limestones.

A diagram of the variation from Fountains fell to Great Whernside,

and to Flasby, will render the result of this complicated investigation somewhat clearer. *(See Diag. No.* 10.*)*

To these two shale series thus distinguished, I give the name of Nidderdale (upper) and Bolland (lower) shale. The latter is seen exclusively in all the west of Craven, the former exclusively in Nidderdale; both of them occur in the south-east of Craven, in the vales of Todmorden, and constitute the general shaly mass along the summit of Drainage, partly associated with, but principally lying beneath the millstone grit of Derbyshire.

The following is a general view of the groups of the millstone grit and shale series in the Wharfedale district.

		Feet.
Upper group	Brimham grit	150 or more.
Middle group	Flagstone and plate group ...	250 estimated.
	Sandgill grit	48 at Greenhow.
	Alternating plates, grits, and coal	345 at Greenhow.
Lower group	Ingleborough grit and coal ...	100 to 300.
	Chert series	
	Main limestone.	

It remains to be determined how to apply this general table to the variable mass of sandstones, shales, and coal, with thin limestones, which occupy the high summits between the northern dales.

Commencing at Greenhow hill we have the following section in general terms, derived from the observations of Mr. Nathan Newbold, in Cock hill level, combined with my own investigations.

		Feet.
Upper grit group 100 to 360	of Brimham, Guisecliff, Poxstones, and the Wharfedale crags ...	
Upper plate group 186 +	Flaggy grit called 'top grit' ...	36
	Ellenscare plate, with laminar chert, coal, and flagstone ...	150
Middle grit	Sandgill grit (coarse grit)	48

		Feet.
Lower plate group 345	Grits and plates, alternating	42
	Fine grit	18
	Grits and plates alternating	120
	Plate	144
	'Top limestone'	13
	Plate	8
Lower millstone grit, 177	Grit	93
	Plate	12
	Grit	48
	Plate	2
	COAL	1
	Grit	21
	Limestone and plate	12
	Great mass of limestone	600 and more.

Our next station will be taken in the upper part of Nidderdale.

		Feet.
Upper grits	of Brimham, &c. only partially seen.	
Upper plate and flagstone group	Consisting of grits and plates, the former mostly laminated and yielding flagstones at several points	200
Middle grit	Strong square blocked grit rocks of coarse texture	30
Lower plate group	Plate ... ... COAL bed of Trope scar, Wogill, &c. Plate, thick ... ... Thin rough gritstone ... Plates, thick ... ... COAL bed in Ramsgill ...	300
Lower millstone grit	Flaggy grit ... ... Pebbly grit .. ... Lower coal seam in Ramsgill...	90 or 120
	Chert, plate, and limestone.	

Passing from Nidderdale to the north we reach the widely wrought collieries of Colsterdale, and have the following series of beds, as observed in Brown beck colliery on the general surface of moorland, including Witton fell. The same beds occurred in the Witton fell collieries, now no longer worked.

		Ft.	*In.*	*Ft.*	*In.*
Middle grit ?	Strong gritstone of Agra crags			51	6
Lower plate and flagstone	Ochry soft sandstone			1	9
	Platy grit			4	6
	Bluish laminated grit and plate ...			63	0
	Gray sandstone	0	7	4	11
	Blue soft stone	1	11		
	Gray sandstone	1	2		
	Gray and blue stone ...	1	3		
	Platy grits and alternations ...			33	
	Solid grit rock			7	
	Platy grit			6	
	Solid gray sandstone rock			5	
	Dark plate			34	
	Hard gray laminated stone ...			21	
	COAL			0	3
Limestone and coal group	Hard gray stone with round balls ...			18	9
	Crinoidal LIMESTONE			15	0
	Hard yellowish cherty stone ...			6	0
	Blue plate			5	0
	COAL (15 to 18 inches) of Wogill and Trope scar			1	4

The coal of Colsterdale, Trope, and Wogill, is identical with that of Scrafton, but lies above that of Parkhead, which corresponds to the lower Nidderdale or Ramsgill, and Greenhow coal.

In Great Whernside we have five hundred feet of plates, flagstones, and solid grits, above the lower millstone grit and coal, of Parkhead. The uppermost rock in Great Whernside may be referred to the upper plates and grits of Nidderdale. The lower grit ranges down Coverdale

on both sides, the middle grit is seen only in patches (on Little Whernside, Great Haugh, Fell crags, &c.) and appears to correspond in position with the top grit of Pen hill.

By the mean of two measures in different directions the summit of Pen hill is about five hundred and fifty feet above the main or twelve fathom limestone. Thus,

	Feet.
Grit rocks of the summit	150
Alternations of plates and flaggy grits, with COAL in the upper part	250
Plates, flagstones or slate sills, &c. ...	60
'Little' limestone, chert, and plates ...	80
Main limestone.	

From Pen hill we look eastward to the Scrafton and Witton coal tracts, and northward to the collieries of Leyburn plain, where coal, twelve to eighteen inches thick, of good quality is obtained about one hundred and twenty feet above the main limestone, and consequently nearer that rock than the coal of Scrafton and Pen hill. Under it is the whole or greater part of the chert series of Swaledale, and above (on the east) comes a millstone grit.

The same coal is worked about Downholme and Hudswell, also above the chert series, and below a thick millstone grit.

We may now turn to Arkendale, where extensive mines and considerable coalworks have laid open the stratification. The section of Old Moulds is given from a manuscript furnished to the Yorkshire Philosophical Society, another which almost exactly expresses the series of the Auld Gang mine in Swaledale, is taken from Mr. Westgarth Forster, and a third for Arkendale from Mr. Winch. *(Geol. Trans. Vol. IV.)*

Arkendale.	Feet.	Old Moulds in Arkendale.	Feet.	In.	Swaledale.	Ft.
Millstone grit	87	'Millstone grit'	120	0	Millstone grit (thickness unknown.)	
Plate	30					
Limestone	2					
Plate	18	Plate	30	0	Plate and hard beds	36
Limestone	3	Limestone	9	0		
Plate	6					
Limestone	3	Plate	3	0		
Plate	25					
Flinty chert	16	'Flinty chert'	36	0	Flinty chert	12
Plate	1					
Crow chert	6	Plate	15	0	Plate and red beds	15
Plate	9					
Second crow chert	12				Crow chert	9
Crow lime	12	'Crow limestone'	18	0	Crow lime and coal	12
		Plate	3	0	Plate	24
First soapy grit	6	Grit	6	0		
		Plate	3	0		
COAL	1	COAL	0	9		
Second soapy grit	7					
Plate	8	Plate	12	0		
Grit	66	White grit	60	0	White grit	60
Girdles	10					
Plate	18	Plate	24	0	Plate	42
Chert	12					
Red beds	12	Little limestone	3	0	Red beds	15
Plate	6	Plate	3	0	Plate	9
Black beds	15	Black chert beds	18	0	Black beds	15
Plate	1	Plate	9	0		
Limestone	2					
Plate	4					
Main chert	18	Main chert	15	0	Main chert	18
	418		387	9		267

Taking our station on Water crag and descending from it in three directions, to the east by Punchard gill, to the south-west by Stonesdale, and to the north-west by Tan hill, we have instructive sections.

In the direction of Punchard gill,

	Feet.
Various grit rocks and plates	416
Coarse pebbly 'millstone grit'	60
Plates, cherts, grits, and thin limestones ...	328
Main limestone.	
	804

In the direction of Stonesdale,

			Feet.	
Various grit rocks and plates			607	
'Millstone grit' of Old Moulds				
Plate				
Upper chert group	Reddish cherty sandstone		60	
	Black plate			
	Platy cherty grits, reddish externally, bluish gray, spotty, shelly and crinoidal within (crow chert)		50	
	Plate and hard bands			
'White grit'			80	
Lower chert group	Plate, &c.		80	
	Dark cherty bed of limestone		2	6
	Plate		40	
	Main limestone.			
			920	

Tan hill colliery, (kingpits),

		Feet.	Feet.
	Various grits and shales.		
Millstone grit	Gritstone	60	162
	Plate	18	
	Grit, coarse	84	
Upper cherts and plates	COAL, 27 in. to 4 ft.		240
	Plate, &c.	120	
	COAL, bad		
	Plate, &c.	120	
White grit			60
Lower cherts, &c.	Black chert, &c.	20	45
	Plate	10	
	Main chert	15	
			507

Thus we find, as a general rule, in Swaledale and Arkendale, thick gritstone rocks above the chert and plate series; in the midst

of the cherty beds a less conspicuous but continuous thick gritstone;—and over all a great mass of upper shales and grits. The chert series becomes almost wholly plate at Tan hill, thus recalling to our memory the equally argillaceous beds of Nidderdale under the coal of Wogill.

According to this view the 'white grit,' lying over the red beds or little limestone of Swaledale is equivalent to the lower or bearing grit of Nidderdale and Parkhead, and the 'millstone grit' of Ingleborough, Penyghent, &c., a conclusion not contradicted by the section of Lovely seat, p. p. 50, 51.

Passing still farther to the south we have the pebbly grit of Lovely seat in Dod fell and Bear's head, at about the same distance from the main limestone, and undoubtedly equivalent to the millstone grit of Ingleborough, Penyghent, and Fountains fell.

			Feet.	
In Ingleborough the top of this grit is			260	above the main limestone.
Penyghent	...	...	240	and has 240 feet of coal shales and grits above.
Fountains fell	...	...	150	and has 100 feet of coal shale over it.
Wharnside	...	...	250	

Turning to the west we find the Arkendale millstone grit characteristically displayed under COAL shales and grits, along the east side of Mallerstang, and in Fell end, its top always three or four hundred feet above the main limestone. Northward it is seen in Dow crag, and several hills north of Stainmoor, and forms the summit of Goldsborough, and other craggy points about Lartington moor, having cherty limestones, grits, plates, and thin COAL beneath it.

That the pebbly grit of Goldsborough is what is called the 'millstone grit' in Professor Sedgwick's Sections of Teesdale, appears to me from specimens and general considerations extremely probable or almost certain. The following section of strata at Old Langdon mine, is taken from Professor Sedgwick (Camb. Trans. Vol. II.), and arranged for comparison with the preceding descriptions.

	Feet.	In.		Feet.	In.	Feet.
Above the 'Millstone grit' ...	101	8				
			Plate	20	8	
			Grindstone sill (coarse) ...	21	8	
			Plate	59	4	
'Millstone grit' (coarse)	33	11	... ...		...	36
Above the firestone	363	10	Plate	89	10	138
			High slate sill (or 27 ft. elsewhere) ...	80	1	
			Plate	54	10	
			COAL (or bituminous shale)	16	0	
			Plate	20	10	
			Gray beds	14	1	
			Low plate sill	15	5	
			Plate	17	9	
			Hazle or slate	5	0	
			Plate	18	0	
			Ironstone (calcareous) ...	8	0	
			Plate	24	0	
Firestone (coarse)...	45	0				
Above the great limestone	164	0	Plate	21	0	141
			Pattinson's sill	7	0	
			Plate	18	0	
			Little limestone (crinoidal) .	7	0	
			Gray beds	9	0	
			Plate	6	0	
			White sill	8	0	
			Plate	7	0	
			High and low coal hasle (COAL between them), in other places not so thick	81	8	
			Great limestone, &c.			
	708	5				

Thicknesses as given by the same author in the 'General Section of Teesdale.'

To complete this analysis of the millstone grit series we may next classify the section of Aldstone moor as given by Mr. W. Forster.

			Feet.	In.
* Above the mill-stone grit, ...	89	Freestone and coarse hazle ...	52	
		Plates and grits	37	
* Millstone grit ...	27			
* Above the grind-stone sill ...	248	Plate and grits	45	
		Freestone	45	
		Alternating grits and plates ...	70	
		Alternating thin gray beds ...	88	
Grindstone sill ...	24			
Above the fire-stone ...	276	Plates and grits	52	0
		Fell top limestone... ...	4	6
		COAL	0	8
		Plates and grits	82	0
		Slate or flagstone sills ...	52	6
		Plate and a slaty bed ...	60	0
		'Ironstone' and COAL ...	4	6
'Firestone,' a coarse grit rock	33			
Above the main limestone ...	174	Plates and grits	67	0
		'Pattinson's sill	12	0
		Plate	18	0
		'Little limestone'	9	0
		Plate	18	0
		COAL	1	6
		'High coal sill'	12	0
		Plate	7	6
		COAL	1	0
		'Low coal sill'	10	0
		Plate	18	0
		Main or twelve fathom limestone.		
	871			

The 'firestone' of Aldstone moor and Teesdale is equivalent to the 'white grit' of Arkendale, and the pebbly grit of Ingleborough, the space below it being somewhat augmented by coal measures, of which no trace occurs in Swaledale, though perhaps the lowest coals

* These parts of the section were taken by Mr. Forster from Healy field in Derwent; those below from Aldstone moor.

of Nidderdale may be analogous. The two Fell top and ironstone coals appear to agree with the two variable coal beds in the upper chert series of Swaledale and Arkendale; the grindstone sill of Aldstone moor corresponds to the 'millstone grit' of Teesdale and Arkendale, and the middle grit of Greenhow; and the millstone grit of the country east of Aldstone moor to the highest pebbly grit of the Yorkshire series designated as Brimham grit. The diminution of the whole millstone grit series from Nidderdale to Aldstone moor is not considerable, the characteristic gritstones preserve nearly the same relative positions, and the other parts of the series retain, amidst many variations, some common features.

Thus there are three rocks called millstone grit, which arrive at their maximum of thickness and importance in different districts, but all are seen in connexion in Nidderdale. COAL, cherts, and thin crinoidal *limestone,* occur both above and below the lower millstone grit: the upper COAL group is the most continuous and valuable. Flagstone and slate occur above the middle grit, and in more than one part of the group below it.

CONSPECTUS OF CERTAIN BEDS IN THE MILLSTONE GRIT SERIES.

Aldstone.	*Teesdale.*	*Arkendale.*	*Pen hill.*	*Nidderdale and Colsterdale.*	*Penyghent.*
'Millstone grit' Grits and plates	Grindstone sill Grits and plates	" Grits and plates		Brimham grit Grits and plates	
'Grindstone sill' Flagstone & plate	'Millstone grit' Flagstone & plate	'Millstone grit' Plates	Top grit Flagstone & plate	Sandgill grit Flagstone & plate COAL	
'Fell top limestone'		'Crow limestone'		Top limestone	
COAL 'Ironstone'	(COAL ?) Flagstone 'Ironstone'	COAL	COAL Flagstone	COAL	COAL
COAL 'Firestone'	COAL 'Firestone'	'White grit'	(Trace of grit)	Bearing grit	Millstone grit
Little limestone' COAL 'Main	'Little limestone' COAL Limestone or	'Little limestone' Chert Great limestone	Little limestone or Twelve	COAL COAL Fathom	Little lime Limestone'

MILLSTONE GRIT SERIES IN CRAVEN.

This is altogether more simple than that previously traced through the northern parts of Yoredale: in all the Bolland district, we see above the great limestone masses only one very thick shale, (with included limestones and ironstones), surmounted by one thick gritstone group. A considerable part of this shale belongs to the Yoredale series, which it has been already seen by the sections of Ingleborough, Penyghent, and Fountain's fell, becomes very much of an argillaceous type in proceeding southward, from Wharfedale and Dentdale. How much of the gritstone belongs to the Ingleborough grit is more difficult to decide. In Pendle hill the following section, more varied than in many other parts of Craven, was noticed in 1827.

Gritstone group of the summit.		Coarse and fine gritstone: some of it holding quartz pebbles.
		Shale containing beds of black argillaceous limestone.
	20	Sandstone.
		Shale.
	50	Alternating limestone (encrinal) and shale.
		Shale, &c.
		Limestone and chert of different colours.
		Shale, &c.
		Great limestone of Clitheroe.

In Longridge fell, though the stratification is very indistinctly seen, the same leading features of the millstone grit series occur as in Pendle hill, but no limestones appear so near to the gritstone, (limestone boulders occur on the fell), which is certainly varied with argillaceous beds and laminar sandstones.

In examining the series on the Lancaster and Garstang side of the Bolland district, where the dip is generally west, we find reason to believe that the gritstone group is rather complicated; consisting of pebbly grits, flagstones, shales, and thin coal seams; the subjacent shales are also varied with ironstones, and layers and nodules of dark argillaceous limestone.

From the Lancaster side of Bolland, we pass by an easy gradation to the rather more varied series of millstone grit rocks on the west of the Lune, where in general terms we have the following succession:

Millstone grit group	Millstone grit, coal, &c. of Dockray moor.
	Alternations.
	Millstone grit of Whittington.
Yoredale series	Crinoidal limestone of Whittington (main lime of Ingleborough).
	Flagstone of Hutton Roof.
	Shales of great thickness with thin fossiliferous limestone and COAL.
	Black limestone beds.
	Shale.
	Lower or great limestone mass of Kirby Lonsdale.

This is evidently a series nearly intermediate between those of Ingleborough and Bolland: and from all my observations I think it probable that in the Bolland district the Nidderdale shales being reduced in thickness, the grits of Grassington and Brimham, (i. e. of Ingleborough and Symon seat), are brought near together, and that the Bolland and Ribblesdale shales belong chiefly to the Yoredale series.

On proceeding southward from lower Wharfedale, across Airedale, and thence along the summit of drainage and western boundary of Yorkshire, the results are somewhat analogous. It must be remembered that we here start from a region (Kettlewell dale, Nidderdale, and Greenhow hill,) where the Yoredale series is extinct or reduced to an argillaceous deposit of no great thickness, but the Nidderdale shales and grits remarkably developed. This character may without much error be ascribed to the whole of Lower Wharfedale; but yet, about Bolton bridge, and still more near Skipton, it cannot be doubted that a great part of the shales, over the black beds of limestone, belongs to the Yoredale series.

The appearances about Kildwick and Keighley lead to the conclusion, that there exist in Airedale two members of the millstone grit series; the lower one descending to the Aire near Kildwick, the upper

one continuing above the river, along Rombalds moor, by Baildon hill, Bradford, and Bramley fall: that between them are shales and a COAL bed of some value, worked opposite Keighley, and continued to Addingham; and below the lower one a great part of the Craven shales. The same general view applies to the valley of Lothersdale; where above the limestone are thick shales, covered by gritstones which appear separated from the range of Sutton crags, by some moderate thickness of shales. The shales lying west of Colne are also to be referred to the Yoredale series; and the thick and varied gritstone series between Colne and Boulsworth might be considered to include both the Ingleborough and Brimham grits.

It follows as a strict consequence that the shales of the deep western valleys of Todmorden, Marsden, &c., and the limestone shale of Derbyshire, are principally to be referred to the Yoredale series; and the thick millstone grits of the same region, viewed as including the whole of the shales, grits, coals, &c. which lie above the Cam limestones in the north of Yorkshire.

The Nidderdale shales diminish southward, and the Ingleborough grit is gradually lost as a distinct member of the group; the Bolland shales appear to retain their thickness as far south as Derbyshire.

Hence appears the propriety of the terms Nidderdale shale and Bolland shale, for these are no where fully developed together, but stand as reciprocal and successive terms; the former being unfolded to a maximum of thickness and variety, in a large area, where the latter is reduced to a very small thickness, or is wholly extinguished.

Craven Shales.—The map will shew, better than any tedious description, the area occupied by the Craven shales and black limestone south of a line drawn from Kirby Lonsdale through Settle and Malham to Grassington, and in general it may be said that in all this tract the strata intervening between the limestone and millstone grit conform closely to the argillaceous rocks called by Mr. Farey, in Derbyshire, 'the limestone shale.' Perhaps the best exhibitions of this thick series are seen

on the Lancashire side of Bolland forest, in Wyersdale, and other valleys about Garstang. The section in the trough of Bolland is very impressive, from the great thickness there displayed; in Pendle hill (west front) it is very well shewn; the Hodder near Stonyhurst, the Calder at Whalley bridge, and the Ribble, in various parts of its course below Settle, near Clithero, display the shales very well. Near Colne it is cut through in the Leeds and Liverpool canal, it occupies considerable heights in the vales of Todmorden, and Marsden, and was penetrated in the long tunnel of the Huddersfield canal under Stanedge. It covers the limestone ridges of Lothersdale, Skipton, and Craco; is rich in fossils at Flasby, and in the vale of Todmorden; is curiously contorted at Bolton abbey, and is almost universally found beneath the pastures of the lower and central parts of Craven. Nodules of ironstone, sometimes septariate (Wyersdale), often fossiliferous (Marsden tunnel), and beds of argillocalcite and chert, (lower Hodder, Whalley, Coniston,) chiefly confined to the lower portions, are the principal causes of variety in this mass of uniform deposits. The thickness of the shales in the Craven district is not easily known. In Pendle hill and near Skipton, it must probably amount to fully five hundred feet, in the trough of Bolland and the valleys on the west of it, a greater thickness may be assigned to it. It is rarely seen to be entirely free from contortions, and the hard argillocalcite layers are commonly bent as completely as the shale.—Sparry veins abound in the latter but not in the former. The texture of the shale is generally fine, it is always bituminous, and except in particular places, and especially in connection with ironstone or limestone nodules and layers, it is seldom fossiliferous.

Coal deposit of Ingleton and Burton.

All the coal of Bolland and North Lancashire belongs to the millstone grit, and corresponds with that of Penyghent, Fountain's fell, &c.; but the coal-field of Ingleton and Burton is of later date, and is so related to the Craven fault, that its relations can only be well understood after reading the account of that dislocation.

CHAPTER II.

Basaltic Rocks, Dykes, Mineral Veins, &c.

ONLY one case of interposed pyrogenous rock occurs in the limestone tract of England to the north of Derbyshire, but this is one of the most extensive examples known in geology, and has given rise to several descriptions. Professor Sedgwick and Mr. Hutton, in particular, have examined this rock with much attention and published different views concerning it.

The toadstone of Derbyshire, whether it be a single or triple mass, may be considered as one great eruption of melted rock interpolated in the limestone series; the 'Whin sill,' as it is called, of Yorkshire, Durham, and Northumberland, is another. They do not correspond in position among the strata; the toadstone lies among lower beds than the Whin sill. They agree in some respects; both being to a certain extent stratiform, irregular in thickness, variously traversed by faults and veins.

The Whin sill is a great mass of greenstone and basalt, extending from near Brough in Westmoreland to the northern parts of Northumberland, occupying a position more or less definite immediately below or in the lower parts of the Yoredale series, never passing downwards to the Melmerby limestone, nor upwards to the main or twelve fathom limestone. In thickness it varies extremely, and within a small compass; there is generally but one stratiform mass; sometimes two, perhaps three, occur, (as near Bavington, Northumberland.) It has never been seen to pass into any of the numerous fissures of the limestone series, nor to send veins into their substance, but it occasionally includes

altered portions of stratified rock, and appears geographically related to certain great basaltic dykes. It is traversed, like all the beds of the limestone series, by mineral veins, sparry fissures, and common faults. The rocks above and below it are (locally) metamorphic. It is frequently columnar, and impresses a like structure on some of the beds in contact with it.

The geological place of the Whin sill is better known in Teesdale, round Cross fell, and along the western edge of the Penine chain from Brough northwards, than elsewhere. From my own inspection, and the statements of miners, I can not doubt that the place of the Whin sill, in Teesdale and Tynedale, and along the breast of the Penine chain, is constantly below, but not far below the Tyne bottom limestone, (which forms the upper part of the great scar limestone of Ingleborough), and above the thick limestone of Melmerby scar. More than this can not be said, because of the variable nature of this part of the series of strata, the augmentation of its total thickness to the north, and the interposition of new limestones, gritstones, and shales, from Murton northwards. It is to this interpolation of new terms that the apparent discrepance of its position at Murton and Rundle beck is owing. This is easily seen by examining a sufficient number of points. It is distinctly seen in this relation, in Hilton beck, at High-cup-nick, in Knock Ore gill, Crowdundle beck, Troutsdale, Maize-beck, Teesdale, and Tynedale. It is from its stratiform character and constant position that the basaltic mass of Teesdale and Tynedale has received its name of 'Whin sill,' in contradistinction to 'Whin dykes;' besides being thus definite in its leading relations to the limestones indicated, its surfaces are generally conformed to their planes of stratification. Of this the Holwick scars, the bed of the Tees near Winch bridge, the High force, and the whole western escarpment, appear to me to furnish decisive evidence. But yet there is some variation in this respect, especially in the cliffs which border the Tees below Caldron snout. In this locality, on the left bank of the Tees, the Whin sill appears in Widdybank scars, and, as Professor Sedgwick describes it, unconformably sweeps over the edges of some of the

stratified rocks. In one locality the trap is based on a singular fragmentary rock of variable composition; in some points it is an argillaceous breccia, reminding one of the red argillaceous rock of Derwentwater; in other parts crystalline limestone, variously coloured and holding different crystals, enters largely into the mixture; some portions have a porphyritic aspect; many look like a volcanic breccia; a few seeming beds occur of a quartzose compound, almost exactly like grauwake, and closely resembling some local beds which cover the slate deposit in Ribblesdale. The variation of the thickness of the basalt is remarkable and sudden: in Hilton beck four fathoms, in Knock Ore gill ten fathoms, in Tynedale twenty fathoms, at Caldron snout in Teesdale thirty or forty fathoms. It is a compound of white felspar and black pyroxene, the latter generally predominating; generally fine grained, but where its thickness is considerable showing also coarse granular parts, like some greenstones of Scotland. Contemporaneous veins of greenstone with large curved crystals, (hypersthene?) pass through the general mass near High force and Caldron snout; strings of spar, quartz, and veins of lead ore (Hilton, Dufton, Trout beck, Tynedale, and Bavington,) occur. The Whin sill is almost in all localities rudely prismatic: the prisms being perpendicular to the planes of the including strata, and not regularly cross-jointed. It appeared in some instances (Miner's bridge) that the lower part of the rock was finer in the grain than the other parts, more jointed and less prismatic,—but the latter circumstance is reversed at the High force.

Considerable *chemical changes* are produced by the trap rock on the limestone, gritstone, and shale, with which it comes in contact or proximity. Not far from the south bank of the Tees, about Unthank and Holwick, and in the river at Winch bridge, sandstone and shale lying *under* the Whin, are greatly indurated, bleached, and full of joints; near the High force some portions of gritstone appear (included?) in contact with the Whin, are bleached in a singular manner, rendered very brittle and full of cracks. Shale or plate is so much altered at the High force in the relations of the joints, that most persons mistake a part of the prismatic masses really composed of

metamorphic shale, for trap, and suppose the latter to rest on limestone. The true series is as follows, proceeding downwards ; *(Diag. No. 12.)*

a Basalt, rudely prismatic, gray with lichen.
b Thin plate, not very much indurated.
c Bed of plate, subprismatic.
d Beds of plate, laminated.
e Thin limestone bed, with a superficial layer of pyrites.
f Bed of hard pyritous limestone.
g Several beds of common dark limestone, with white shells and corals.

The limestone here seen below the Whin, does not present any remarkable characters implying the action of heat, (unless we except the pyritous layer at top), but in the grand precipice of White force, the limestone which supports the trap, and is *in contact with it,* is converted to granular limestone, and plate is greatly indurated.

The beds *above* the Whin sill are also locally much changed in struc-tnre, texture, and aspect. The effects of heat are in some places more traceable above the Whin than under it; but they are no where important unless the mass of whin be considerable. Below Winch bridge, the Whin is thin, and limestone lying over it, (Tyne bottom limestone of Forster), is only partially affected. About half a mile below Winch bridge, I found plates alternating with three limestones; the lower one was black within, and compact, the middle one was black and granular, both rather prismatized, the upper one blue, and partially pyritous; Professor Sedgwick found, near this locality, more decided effects of heat. (Camb. Trans. Vol. II, p. 171.)

The limestone lying above the Whin, in a circle round Caldron snout, is greatly changed from its usual aspect. The Tyne bottom limestone alluded to is, in this district, generally of a dark blue or blackish colour, and close texture, occasionally, however, containing crinoidal fragments and columns. On Widdybank scar, which seems about the point of maximum thickness of the Whin, this limestone is a

loosely aggregated mass of granular carbonate of lime, resembling coarse white sand. These calcareous sparry grains seem to be obscurely dodecahedral, and amongst them lie a few sparry crinoidal columns. As we recede from this centre, the limestone resumes by slow degrees somewhat of its ordinary character, passing through stages of white, bluish, and blue granular limestone, which grows more and more compact, darker, and harder, till its ordinary aspect is restored within a mile in the directions where the Whin is rapidly attenuated, but at greater distances where its thickness remains considerable. Under the same Widdybank scars Professor Sedgwick ascertained the production of olive brown, or green garnets, in the cells of the anomalous fragmentary bed which supports the trap.

Since it is about Caldron snout that the Whin exhibits most thickness, and the greatest effects of heat in the rocks both above and below, it seems a plausible hypothesis to consider it as having been raised up through an opening in the lower limestone rocks at this place, and to have flowed hence in all directions for some distance, growing however very thin to the west, and vanishing totally to the south. The long ridge of basalt which extends down Teesdale, from Caldron snout to Lonton, may very probably indicate the line of a volcanic fissure, communicating with the presumed great opening at Caldron snout. Other such openings and fissures, along the line from Brampton to Belford, will explain the general conformity of the Whin sill to the limestone series.

But we may now inquire what proofs occur of mechanical disturbance produced by the eruption of the basaltic lava? On this subject Professor Sedgwick has left little to add to his very satisfactory description of the phenomena at White force, (Cronkley scar), in Widdybank scar, and near Lonton; I shall therefore adopt his descriptions, merely adding one additional instance, not visible when he made his survey.

Lonton.—Here, in the Lune, portions of the subjacent hazle are

raised up, and their free ends immersed in the lower parts of the Whin sill.

Widdybank.—The anomalous breccia above described, and the unconformity of the Whin sill to the subjacent beds, are the principal facts here observable.

White Force.—At this fine waterfall the thick Whin sill rests in one part on granular limestone, thirty feet thick, and in another on two beds of limestone separated by a thin bed of indurated shale. Portions of the upper members, limestone and shale, are raised up and enveloped in the Whin, which penetrates in two wedge-shaped expansions between the limestones and shale.

High Force.—In the new road from Brigghouse Inn to the waterfall, a small section was made through a point of the Whin sill, about fifty yards below the High force, and an interesting fact was disclosed. At the High force itself not the least trace of mechanical force has been observed at the junction of the trap and shale; but here a limited mass of gray sandstone rock, lying below the Whin, has been partially entangled in it, as the Diagram, No. 11 will shew better than any description. Near the junction surfaces, both the Whin and the sandstone are greatly altered; the former is ochraceous and softened, the latter calcined to whiteness, and singularly fissured. In all these cases the mechanical movements are confined to the beds *below* the Whin.

From near the eastern end of the escarpment of the Whin sill in Teesdale, arise two or three great basaltic dykes, which have been examined by Professor Sedgwick, and possess a high interest in coal-working and theoretical geology. The Whin sill, being about a quarter of a mile from the river Tees on the south side, ceases to be visible at about half a mile from the junction of this river with the water of Lunedale. At this junction one of the Whin dykes is supposed to cross the valley pointing towards the apparent termi-

nation of the sill, and Lune head. (or W. S. W.) It is seen on Eggleston common, crosses Eggleston burn with observed bearing E. N. E. or E., 20° N., breadth thirty-three feet, nearly vertical. In the hill above the dyke is exposed in a plantation, between cheeks of shale converted to a whitish soft rock, such as that often found below the Whin sill, called 'pencil bed,' in which many vertical joints appear *parallel to the dyke*. Along the south face of the dyke some lead ore was obtained, for which shafts were sunk and a level driven. The ore lay in what may be called mineralized trap. Further to the east the range of the dyke continues to be traceable by the valley of the Redburn, north of Hamsterley, and near Witton-le-Wear, Whitworth and Tudhoe, to Hett and Quarrington, always preserving one direction, viz. E. 19° 20°, 21° or 22° N. At Quarrington it passes through Crow Trees colliery, dividing and charring the five quarter and high main coal seams, diminishing in breadth as it approaches the surface. It does not divide the superjacent limestone; but whether this arises from the contraction of the fissure, or from anteriority of date, is not certainly known. Its breadth at the surface at Crow Trees is six and a half feet, at Tursdale nine and a half feet, at Bitchburn fifteen feet, at Hamsterley twenty-three and a half feet, and at Eggleston burn thirty-three feet. Thus its breadth diminishes from the basaltic region toward the E. N. E., and it also contracts upwards or toward the surface. It is supposed to extend up Lunedale, by Greengate, and Womersgill. The substance of this dyke is a fine grained basalt of bluish aspect, it is not of prismatic structure, but full of vertical and transverse fissures which are often lined by ochraceous partings.

Another dyke, also appearing to originate from the great Whin sill at its eastern end, is seen on the banks of the Tees, half a mile below the confluence of the water of Lunedale, and is imagined to range through the limestone country north of Lunedale. It is next observed crossing Eggleston burn, a little east of that noticed above. It has a bearing of E. 5° N., is nearly vertical; breadth fifty-four feet; a narrow part on the south side is soft, the northern

part is hard blue Whin with large crystals of felspar. It divides a coarse grit rock, (firestone of Aldstone moor, Ingleborough grit of Yorkshire) and consolidates it exceedingly. This same sandstone is often equally hardened by veins, so as to cause great expense in drifts. Obscure traces of this dyke may be found on the moors along a line E. 10° N., and at Woolley hills, two miles east, we find on this line the great Cockfield fell Whin dyke. At Woolley hills the dyke bears S. of E.: it is quarried extensively, appears very wide, and somewhat *arched* above. The stone is blue, not very compact, and includes large crystals of felspar; it resembles in some respects the basalt of Coley hill near Newcastle. The coal of Butterknowl is charred by it, especially on the north side; it is there fifty feet wide, ranges S. 65° E., seems divided into several parts or strings above, but is solid underneath. A remarkable circumstance connected with it is the contraction of its mass to a breadth of nine feet in this colliery at fifty feet depth, and it is supposed to retain only a very narrow breadth for some distance westward toward Woolley hills. Its direction undulates, and changes in the colliery at Butterknowl to S. 88° W.— which carries it to Woolley hills. In one place it is shifted horizontally twenty-two fathoms, by a slip of seven fathoms ranging north and south.

At Cockfield fell the dyke expands laterally, and seems to overlay a part of the coal series; it presents a very remarkable pyriform expansion at Bolam above West Aukland, crosses the Tees between Yarm and Stockton, is quarried at Stainton and Langbargh, lies in prisms across Clifton rigg, ranges down Eskdale to Egton, and thence on the moors across May beck, where it terminates its long course of seventy miles in oolitic rocks. Effects corresponding to igneous agency accompany its whole course. *(See Illust. of Geol. of Yorksh. Vol. I.)*

Besides these Whin dykes Mr. Hutton mentions one passing east and west through Warcop fell and cutting Long fell and Roman fell. A basaltic dyke also crosses by Tyne head, in a direction N. N. W.

Concerning the Whin sill, three things are far from evident: 1. The time of its origin. 2. The manner of its introduction among the limestone strata. 3. Its relation to the two great Whin dykes just described. On these subjects Professor Sedgwick and Mr. Wm. Hutton have delivered contrary opinions. My own investigations lead to the following deductions.

The Whin sill is of date anterior to the east and west lead veins of Tynedale, Teesdale, and the Penine chain: for it is divided by these veins of fissure, exactly as the limestones are, and yields the same metallic riches in considerable proportion. At Troutbeck foot an intersection of veins yielded lead ore more abundantly in basalt than in any other stratum. It has been before shewn that these veins appear so related to the great axis of convulsion as to be a consequence of these disturbances. The Whin sill then is older than most of the saliferous system. It follows inevitably that the Cockfield dyke, which at its eastern end divides the oolitic strata, is not coeval with the Whin sill. But yet its direction and attendant phenomena, as well as those of the Quarrington dyke, indicate a centre of eruptive force in Teesdale, and we thus perceive reason to believe that more than one eruption of basaltic lava rose through openings in that valley at distant epochs of time.

Was the basaltic lava poured out on the bed of the sea at one or several epochs during the deposition of the limestone series, so as to be quickly covered by these deposits, and thus be interstratified amongst them; or did the eruptive lava during a later period force its way into the previously deposited rocks, along their surfaces of stratification, and thus elevate the whole mass of superjacent strata, as appears to have happened on a smaller scale in many situations? Professor Sedgwick, in advancing the latter view, appears to have been much influenced by the local metamorphism of adjacent strata, by the partial unconformity between these and the Whin, and occasional inclusion of portions of their substance in its interior; Mr. Hutton, on the contrary, has given more importance to the leading fact of its general *conformity* over a

vast area to the beds above and below. To me both these observations appear of great importance, and it seems clear that the basaltic lava spread over the bed of the sea at intervals, during the deposition of a portion of the carboniferous limestone, that in certain places its eruption was accompanied by some violence, but no where directed by so immense a force as one capable of opening horizontally the whole limestone series for many square miles. Such an inconceivable force must have filled every fissure of all the rocks from Middleton to Hartley burn, with dykes of basalt, ranging in all directions, while in fact almost nothing of the kind is known, and even around Caldron snout, only very small mechanical effects are due to the Whin, and these are, as far as I have seen, wholly confined to the subjacent beds.

It is not necessary to suppose that only one such submarine flow of basalt occurred, any more than to confine it to one opening; the double or triple Whin beds of Northumberland, sufficiently countenance a belief, that the region was often disturbed by such eruptions.

It is remarkable that the alteration of limestones and shales is most conspicuous near Caldron snout, where the mass is greatest; it is in this part only, that the strata are much changed *above* the Whin; and it is perhaps the only locality for perfectly granular limestone. If we suppose a deposition of limestone to happen upon the bed of the sea, some time after the production of the melted rock beneath, the natural result would be a change of the limestone, only or principally where the mass of igneous rock was very great; in all other places the necessary heat would have escaped.

If this reasoning be admitted to prove the Whin sill to be of the same geological period as the attendant strata, it follows that the dykes are wholly independent of it, and posterior to it, though doubtless derived from the same plutonic focus.

Other Dykes.—Besides the dykes already mentioned in connection with the Whin sill, I am acquainted with only two in Yorkshire,

and these are of a very different character. They occur at Ingleton, on the line of the Craven fault, accompanied and much confused by an extraordinary mass of contorted slaty laminæ, which intervene between the slate quarries and the lower limestone range. The most distinct of the two, only a few feet wide, is to be seen projecting like a wall from the left bank of the stream, about one hundred yards below the slate quarry. The composition of the stone is remarkable and uncommon. It is a fine grained crystallized compound of red felspar, light coloured hornblende, and mica,—occasionally holding large masses of the same red felspar, with broad flakes of mica in them. It may as well be called hornblendic granite, or micaceous syenite, as greenstone; I found a loose fragment of the same rock in Knock pike (1827), and it appears probable that further researches may shew a closer connexion than can be proved at present between the dykes of Ingleton, and Knock pike, and the granitic mass on the north-west side of Dufton pike.

Dun Lime.—The peculiar condition of the limestone expressed by this name has been already explained, p. Limestone in this condition occurs under the following circumstances principally. *First,* along the lines of fault or disturbed stratification as near Kettlewell, along the Craven fault near Ingleton, in the 'rearing beds' of Pendle hill, and part of Bolland. The best exhibition that I am acquainted with is on the southern end of Twisselton scar, where at a small anticlinal axis, north of and parallel to the Craven fault, dun limestone beds, thirty yards in thickness, stand vertical. *Secondly,* along the line of a vein, as below Middleton, on the banks of the Tees, and near Kettlewell. *Thirdly,* in the lower part of the limestone series, as in particular about Brough, and in the valley of the Gelt. This state of the limestone does not appear to be dependent on the proximity of igneous rocks, for it scarcely occurs near the Whin sill of Teesdale; but appears to be definitely connected with the lines of dislocation of strata, and may be plausibly referred to some chemical or electrical agencies developed along these lines.

Mineral Veins.—The principal products of the mountain limestone tract of Yorkshire are sulphuret of lead, carbonate of lead, sulphuret of copper, sulphuret of iron, carbonate of iron, and oxide of iron, sulphuret of zinc, carbonate of zinc, and white oxide of zinc; of these all, excepting the iron ores, are invariably connected with spars veins, fissures, or rock dykes: and these are the most general repository for iron pyrites, which also occurs near the junctions of sedimentary rocks with the Whin sill.

It is important to remark, that no instance is known, along the Penine region, of any one vein being continuous from the slates of Cumbria into the mountain limestone tract; no case is, I believe, known of any vein being worked in old red sandstone; no vein has been *worked* (in Yorkshire) above the upper or Brimham millstone grit: though lead ore has occurred in veins in coal seams above that rock, and strings, and nests of lead ore, and copper ore, have been met with in magnesian limestone at Nosterfield, Farnley, Newton Kyme, and Warmsworth.

Calamine and white oxide of zinc occur in considerable quantities, chiefly or wholly in the lower scar limestones, as in Bolland, near Whitewell; near Malham; south of Wensleydale it is in the lower scar limestone, principally, that the lead mines of Greenhow, Nidderdale, Grassington, Kettlewell, Arncliffe, Hardflask, and Ingleborough, are or were worked; but to the north of Wensleydale the Cam limestones become the most productive. In the mining districts of Greenhow, Grassington, and Kettlewell, veins yield ore both in the limestone and millstone grit series. Veins have been found more or less productive in the millstone grit series, south of Lothersdale, about Greenhow hill, Grassington, Buckden pike, near Leyburn, and in the line of the Auldgang vein in Swaledale and Arkendale. Mines are worked in the Whin sill, at several points, north of Maize beck.

From these facts it follows, that the dependence of particular metallic products on particular series of rocks is principally a local phenomenon, without general application; but on more minute analysis of the

phenomenon, it is found that, in a given district, certain beds generally *are*, and others generally are *not* productive of metallic treasures. A particular vein, for example Fryerfold vein in Swaledale, traverses millstone grits, plates, and cherts; main limestone; grits and plates; underset limestone, grits, plates, &c.; and it is a matter of experience that among these beds only the consolidated siliceous and calcareous beds are productive; in the argillaceous plates the veins are mostly 'dead'. Also if, in consequence of displacement of beds along the vein, solid rocks on one cheek are opposed to argillaceous beds, the vein (unless in mining language 'very strong') will probably be unproductive and partially contracted; but if solid rocks on one side are opposed to the same or to other solid rocks, the vein is in a favourable condition for bearing ore. Hence the well known distinction of 'bearing beds' and 'dead beds', so important in practical mining and geological theory. The sides of the vein being called its walls or cheeks, the favourable and unfavourable conditions of a vein may be reduced to the following simple formula:

Cheek A.		*Cheek B.*
Argillaceous.	Vein unproductive and narrow.	*Argillaceous.*
Argillaceous.	Vein partially contracted, and poor.	*Gritstone or limestone.*
Gritstone.	Vein irregular in its produce.	*Gritstone or limestone.*
Limestone.	Vein in the most favourable state.	*Limestone.*

In a country like the Dales of Yorkshire, the nature and thickness of the 'quick' or bearing beds, extent of them along a vein, and the dip of the strata, being well known, the probability of a vein yielding good produce at a particular point is reduced to a problem of plane geometry; and every good miner determines accordingly, in what line, and at what elevation, to commence his water drift or level.

It has been attempted from these facts, imperfectly understood, to draw a conclusion in favour of a close and necessary dependence between the produce of a vein, and the chemical *nature* of the containing rocks, so as to permit an inference that the vein itself was *segregated* from the opposite rocks, or else that the whole is of

contemporaneous origin. The latter point will attract attention, in another chapter, the former is totally void of evidence, and seems an unnecessary hypothesis, after the proof given, that the real dependence, *in this region*, is on the consolidation of the walls, and openness of the fissure.

One peculiar geographical relation may be here mentioned, though it perhaps rather belongs to another chapter. Copper ores are little known in the limestone districts of the north of England; except about Conishead Priory, in some parts of Aldstone moor, near Brough, and Middleton Tyas. It appears from the experience of the Aldstone moor mines, that copper ores rather affect the lower portions of the limestone series there, and in consequence are rather less rare towards the western or Penine escarpment. What is known in Yorkshire on this subject, is of no importance; but it is remarkable, that there is a line of mineral deposits, passing north by west, parallel to the eastern range of the carboniferous deposits, principally yielding copper ore; in magnesian limestone at Newton Kyme, and Farnley, and in main limestone, at Middleton Tyas.

CHAPTER III.

Symmetrical Structures of Rocks.

THE fundamental rocks having now been described, it remains to determine what changes have happened to them since their deposition. The principal effects which are to be traced are due to subterranean movements, pervading heat, and molecular attraction. To treat of these effects in the order of their occurrence may be difficult, yet without some attempt to view the processes in their historical connection, we are in danger of losing sight altogether of their real and necessary dependence.

The consolidation of stratified rocks is a natural consequence of the pressure of the superincumbent masses, whether heat was applied or not: yet, since we know that many of the older strata were formed under oceans as shallow as those which received the more recent deposits, and have not been covered by any great thickness of superior rocks, it becomes evident that the higher state of consolidation in which we find them must be ascribed to another cause. It is a certain truth that the consolidation of stratified rocks is directly in proportion to their antiquity: for, omitting cases of rocks locally metamorphic by contact with igneous masses, we shall find in each of the three most abundant stratified rocks—calcareous,—argillaceous,—and arenaceous,—a decreasing scale of consolidation, from the primary to the tertiary systems.

The argillaceous slates of the primary period are, as to chemical and molecular composition, very analogous to the argillaceous beds of the mountain limestone system; but they are more indurated, have more

symmetry of structure, and impress the mind more firmly with a notion of some kind of crystallization. This impression hardly occurs at all to the observer of the clays of the oolitic and other more recent systems of the rocks. Similar remarks apply to the calcareous and arenaceous portions. All this seems in favour of the opinion that the consolidation and structural changes are due rather to length of time than to any peculiarity of agency. But there are facts to render this inference extremely dubious; especially this, that the consolidation of the grauwacke rocks must have been completed before the formation of the old red sandstone conglomerate of Cumbria,—and that of the mountain limestone before the age of the Brockram beds of Stenkrith. May we then venture to consider the degree of consolidation as depending on the degree of heat applied, as well as on pressure and the duration of its influence? This question will be better answered after we have considered the structural peculiarities of the rocks.

Besides the *stratification* or bedding of rocks, and the parallel or oblique *lamination*, which may often be noticed in their beds, both which are original or formative structures, there is another pervading alike stratified and unstratified rocks, viz., the *divisional structure.*

All the *apparent* divisional planes of rocks, which are not coincident with surfaces of stratification, or laminæ of deposition, may in general be called joints, but it is convenient to adopt the term *crack* for such as are confined to only one bed of stone, *joints* for such as pass through one or more similar beds, and *fissures* for those greater divisions which dissect whole formations. *(See Guide to Geology.)*

The most remarkable of these latter may be called master-fissures. The non-apparent, however real, fissility of rocks, exemplified specially in slate, is called *cleavage.* We shall first treat of joints.

Joints in relation to the nature of rocks.—All rocks are traversed by joints, because *concentration from expansion* (whether aqueous or igneous) has happened to all rocks;—but in rocks of different chemical and

molecular constitution, the joints vary in number, regularity, direction, and other characters.

In pyrogenous rocks, it generally happens that the planes of their joints are perpendicular to the bounding surfaces, (where the cooling commenced,) so that in the stratiform basalt and greenstone of Teesdale, their intersections are vertical, but in the great basaltic dyke of Cockfield, horizontal. It also happens that the joint-planes are not in general continuous through one another, but from each intersection a new plane arises, thus breaking the whole rock into prismatic masses, and leaving no doubt in the observer's mind of the *contemporaneity of all the divisions*. There are nevertheless, in certain districts, a few master-fissures observable. This prismatic structure is beautifully exhibited at the High force in Teesdale, where the basalt has impressed the same forms upon the subjacent shale, so exactly, that it was only on a second visit to that romantic spot that I was undeceived as to the nature of the phenomena. At some distance above and below, this structure entirely vanishes. *(See Diag. No. 12, and page 79.)*

In the stratified rocks of Yorkshire we notice, but can hardly describe, peculiar characters of the joint structure corresponding to each different rock. Throughout the slate and carboniferous tracts the laminated argillaceous rocks are most minutely and perfectly jointed, the thick massive beds of sandstone irregularly cracked rather than fissured, the limestones locally cracked, always jointed, and fissured. In the magnesian limestone, the laminated upper beds are regularly and symmetrically jointed, but the thick yellow limestone beds, exhibit little of this character. The laminated lias clays are as regularly jointed as some of the coal shales, but the more homogeneous clays of the oolitic series above, shew this character feebly; the limestones are jointed and fissured, and the sandstones irregularly cracked and fissured. In all systems of rocks, conglomerates of all kinds have little symmetry in their divisional planes, but are traversed by great fissures: coarse sandstones are more irregularly divided than finer rocks, and laminated shales lose on becoming sandy or calcareous most of their minute

jointing, but in the latter case contain more secret or dry cracks. Very thick and uniform masses of limestone exhibit prismatic structures as in pyrogenous rocks.

One more relation of joints to the nature of the rock is to be noticed. The width between their faces varies to a considerable extent, so that the sum of the spaces which they leave in the rock is greatest in limestone, least in fine clays and coal, and of an intermediate amount in gritstone and cherty beds. This fact is best seen by contemplating some of those great fissures which pass through all the beds of a mountain limestone district; and widen to the extent of some inches or a foot in the limestone, but contract to a narrow chink in the plates.

Another relation to rocks is observable. Joints are most numerous and symmetrical in the *older rocks*. Compare for instance the laminated grauwacke of Westmoreland with the plates of the limestone series of Yorkshire; these with the laminated lias of Whitby; the lias with the Oxford clay or Kimmeridge shales; and generally the argillaceous terms of any series below the chalk with those above it. Again, compare the thin bedded carboniferous and magnesian limestones; either of these with the lias limestones; any of these with the forest marble or Wealden groups; or let the flagstone below the millstone grit be compared with that above it, and both with the flagstones of the oolitic or Wealden formations.

It may occur as an objection to this conclusion that gneiss and mica schist have less of this structure than laminated sandstones: but to this two remarks apply: first, these rocks are almost always very coarsely grained; and secondly, where, as in the country about Dalnacardoch, they are of finer grain, the jointed structure appears in great perfection. In these old rocks the variation of joints in the ratio of the lamination is well seen by comparing the black limestone of Glen Tilt, with the thin bedded rock of Loch Earn—the former being fissured, the latter minutely and regularly jointed.

From all that has been said we may collect these general results. There are peculiar types of jointed structures for rocks of different mineral composition; in each of these rocks the type is variable in proportion to the lamination of its mass and the coarseness or fineness of its granular texture; and the number and symmetry of the joints augments with the age of the rock.

Relation of Joints to other Structures in Rocks.—The geometrical characters of joints may be considered with reference to the surfaces of stratification and laminæ of composition (where these are not parallel to the former;) and the general surface and polar points of the globe.

First. The planes of the joints are in all the secondary and primary rocks independent of the laminæ of composition; of this every obliquely laminated gritstone or oolite affords complete proof.

Secondly. In limestones of all ages generally the planes of the joints, both great and small, are perpendicular or nearly so to the surfaces of stratification. The internal cracks in the laminated limestones shew amidst many variations the same general law.

Thirdly. In laminated argillaceous secondary rocks the joints are chiefly perpendicular to the surfaces of stratification, but some instances occur, and they are not unfrequent in the plates of the mountain limestone, of joints oblique to these surfaces. In the primary argillaceous deposits the joints, perpendicular to what are presumed to be surfaces of deposition, are complicated with many others oblique to them in different directions, (as already exemplified in the description of the Craven slate rocks, p. p. 6, 7, 8.)

Fourthly. In laminated sandstones the joints belong to the same general description as those in shales, but oblique joints are less frequent. In block gritstones the joint surfaces, though far less regular than in limestones, have the same vertical relation to the surfaces of stratification.

It is easy to see how these circumstances impart to the several rocks definite features, which characterize local districts, and make that variety of rock scenery remarkable in good pictures of different regions.

At a distance of many miles the mountain limestone scars of Yorkshire distinguish themselves by form as well as other marks from the brows of gritstone and the peaks of slate, and all these are differenced by the observing eye from colonnades of pyrogenous rock.

Geographical relation of Joints.—We may next compare the joint-planes to the general surface and polar points of the globe. The relation of joints to horizontal planes is through all the secondary and tertiary strata (uninfluenced by local pyrogenous rocks) accidental; being in fact dependent on the inclination of the surfaces of stratification. But in the slate districts, the question is more difficult. If it be correct to consider the 'spires' of the Ribblesdale slate surfaces of stratification, (see p. 8,) the constant verticality of the N. and S. joints may perhaps be really dependent on their crossing the strata nearly at right angles to the dip, while the variously oblique and horizontal joints seem reducible to no exact relation either to the surface, the stratification, or the cleavage.

But there remains a very interesting subject of research, on which it is possible to acquire precise information, viz. the relation of the direction of the joints, as measured on a horizontal plane, to the polar points of the globe. It has already been stated that in the slate tracts of Craven vertical north and south joints are eminently characteristic constituting the ends of the 'spire.'

In old red sandstone at Brough, N. 15° E.

In fifteen observations of long joints in the lower mountain limestone series I found the directions as under.

Horton in Ribblesdale	...	N. W.—N. W. by N.—E. N. E.
Kettlewell ...	...	N. (2) E. (2) ...
Gale near Hawes	...	N. W. (2) N. E. by E.
Ravenstone dale	...	N. N. W. ... ...
Millgill near Askrigg	...	N. by W. W. by N. ...
Nidderdale ...	...	N. N. W.
Malham water ...	...	N. W.
Mallerstang ...	...	N. W.

In thirty-five observations of the Yoredale series the following were recorded:

Yoredale middle and lower groups	Under Little Whernside	...	N. N. W.—N. by W.
	Opposite ditto ...	...	N. N. W.
	Caldbergh ...	...	N. N. W.—E. N. E.
	Waldendale ...	...	N.
	Mallerstang ...	...	N.—E.
	Addleburgh ..	...	N. by W.
	Starbottom ...	...	N. by W.
	Garsdale flags ...	...	N.—E.
	Middleton in Teesdale	...	N. 30° W.—N. E.—E. N. E.—W. N. W.

Cam group.—Underset plate, Bishopdale,		N. by W.
Underset chert, Water crag ..		N.—W. N. W.
Main lime, East Witton	...	N. N. W.—E.
Caldbergh	...	N. N. W.—E. by N.
Swaledale	...	E.
Middleham moor		N. N. W.
Melmerby	...	N. N. W.
Rokeby	...	N. 5° W.—N.
Middleton Tyas		N. 10° W.—E. 15° N.—N. E.

Black Craven lime-stone.	Lothersdale ...	...	N. W.
	Whalley ...	...	E. N. E.
	Thornton ...	...	N. N. W.
	Bolton	...	S. W. by W.

Seventeen observations in the chert group above main lime.

Water crag ...	...	N. W. by N.—N. E.
Stakefell ...	...	N. by W.

Leyburn	... ...	N. N. W.—E. N. E.
Middleham moor	...	N. N. W.
Melmerby	... ...	N. N. W.
Richmond	... ...	N. W.—N. W. by N.—E. N. E.—N. 25° W.—E. by N.
Near Gilling	... ...	N. N. W.—E. N. E.
Hudswell	... ..	N. N. W.
Brackenbrough	... ...	N. 30° W.—E. 25° N.

Thirteen observations were made in other parts of the millstone grit series.

	Kirby Overblow	... ...	N. N. W.
	Blubberhouses	... ...	N. by W.—N. N. W.—N. by W.—E. N. E.
	Dacre ...	... ...	N. N. W.—E. N. E.
(Flagstone.)	Masham moor heads	...	N. N. W.—N. W. by N.—E. N. E. E. by N.
(Flagstone.)	Colsterdale	... ...	N. N. W.
(Flagstone.)	Pen hill	... ...	N. 20° W.

In the coal series of Yorkshire the joints range N.—N. by W.—N. N. W.

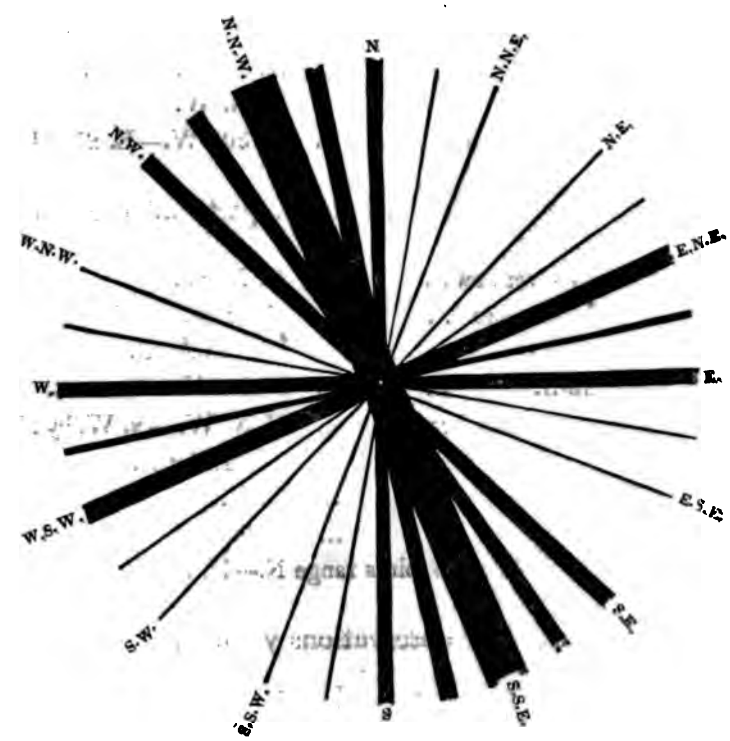
In the magnesian lime four observations yield the following results:

Newton Kyme	... ...	N. N. W.—N. W.—N. N. E.
Nosterfield	... ...	N.

GENERAL TABLE OF RESULTS FOR THE SECONDARY ROCKS OF YORKSHIRE.

Names of Formations.	*No. of Obs. in Yorksh.*	*W. by N.*	*W. N. W.*	*N. W. by W.*	*N. W.*	*N. W. by N.*	*N. N. W.*	*N. by W.*	*N.*	*N. by E.*	*N. N. E.*	*N. E. by N.*	*N. E.*	*N. E. by E.*	*E. N. E.*	*E. by N.*	*E.*
Magnesian limestone	4				1		1		1		1						
Coal	3						1	1	1								
Millstone grit	13					1	5	2							4	1	
Chert group	17				1	4	6						1		4	1	
Yoredale series	35		2		1	1	8	5½	5½				2	1	3	2	4
Lower limestone	15	1			4	1	2	1	2					1	1		2
Old red sandstone	1									1							
Whin sill	1																1
	89	1	2	0	7	7	23	9½	9½	1	1	0	3	2	12	4	7

The following diagram represents the result of the investigation by breadths of shade corresponding to the frequency of long joints or fissures, parallel to each radius.



The jointed structure, thus investigated, is an essential and necessary part of the structure of rocks, not to be viewed in the light of geological accidents, depending on subterranean movements, but affording evidence by the constancy of its direction in large districts, of the action of some very general cause, capable of controuling the consolidation of the rocks so as to cause the separation of the condensed masses along certain parallels. If this be not really crystallization, it is to be considered as a symmetrical aggregation of the molecules. The subject will again come under review, and it is only necessary now to observe that the direction of the joints is independent of at least all the minor faults and dislocations of the strata, which are altogether phenomena of subsequent origin.

CHAPTER IV.

Effects of Subterranean Movements, &c.

After the deposition and consolidation of the strata they were subjected to disturbing forces originating at some depth below the surface of the earth, and thus broken in many directions, and partially uplifted and depressed.—In the country now under examination the operation of these forces is variously exhibited in axes and centres of elevation, and other great displacements of strata, accompanied in a few instances by dykes of ignigenous rock, and very often by mineral veins.—The time and circumstances of these accidents are of high geological interest.

THE PENINE SYSTEM.

(See Diag. 1, 2; and Sections 1, 2.)

The whole escarpment of the Penine chain from Brampton to Kirby Stephen in a direction to the S. E. by S., and thence to Kirby Lonsdale nearly S. W. by S. is caused by an immense disruption coincident with the elevation of a ridge of partially exposed slate rocks. The effect of this disruption is the relative displacement of the strata on the two sides of it, (in one part to the extent of a thousand yards at least,) for a length of fifty-five miles. Perhaps the whole world does not offer a spectacle more impressive to the eye of the geologist than that afforded by the contrast between the mighty wall of mountain limestone rocks soaring to the height of two thousand five hundred feet, above the vale of the Eden, and the plain of Carlisle, and the level beds of the red sandstone deposited in later times at the foot of the ancient escarpment, upon the relatively depressed portion of the same mountain limestone series.

At the northern termination of the Penine chain, this great disruption ends, and another (which may indeed be considered as the

same continued at right angles) parts from the same point, toward the east, and causes a relative depression of the limestone strata on the north to an amount which cannot be estimated at less than two thousand feet. This great dislocation continues in its eastward course with some deviations for fifty miles to the sea side north of Newcastle, where it affects the magnesian limestone, as well as the coal measures, and thus gives us approximately the date of the convulsion. Coal measures of the series above the millstone grit appear on the north side and at the west end of this dyke opposite some beds of the middle portion of the flag and limestone series.

From the southern end of the Penine chain near Kirby Lonsdale another or rather a double line of dislocation takes its course E. S. E. for thirty miles to Wharfedale, and perhaps beyond, of which the effect is a relative depression of the southern side of from one thousand to three thousand feet according to the locality. It is interesting to observe that on the south side of these dislocations in one spot a coal field occurs, almost precisely under the same circumstance as that before noticed near the northern end of the Penine chain.

The leading effects of the Penine fault are sufficiently obvious, but the lesser circumstances connected with it are not easily seen and have been little attended to. On the line of the northern branch to the east, (ninety fathom dyke or Tynedale fault,) no locality is so interesting as that often described yet ever new exhibition of it at Whitley and Cullercoats on the sea side north of Tynemouth. In the sea cliff it is seen to dislocate not only the coal measures but also both the beds of the Rothetodteliegende and magnesian limestone, the beds on the north or depressed side *dipping towards* the fault. The plane of the dislocation deviates here no less than 59° from the vertical, underlying to the north; the surface of the overlying yellow sandstone being marked by numerous parallel flutings, precisely along the dip of the fault, and such as may be conceived to have been produced by a movement like that of an enormous planing machine. This important fact confirms the conclusion which from many other reasons is probable, that the whole

of this great dislocation was accomplished by sudden and violent displacement. The fault ranges hence N. 69° west—passes through the Gosforth and Kenton collieries, where the extent of its throw (always down to the north) is proved to be above one hundred and fifty-six fathoms; even without including a considerable curvature of the beds on the north side. The dip toward the fault of the depressed beds on the north side, continues to be observed along this dyke—as it proceeds westward. The remarkable detached coal tract of Hartley burn on the north side of the dyke, containing the lower beds of the Newcastle series, dips also, in conformity with this rule, to the south. The general bearing of the fault from Hartley burn to Cullercoats is *E. by N.*

Along the S. E. course of the Penine fault from Brampton to Brough we have principally to remark the elevation of the conical slate hills called Dufton pike, Knock pike, Keisley pike, and Murton pike, which rise higher than the lower edge of the Penine limestone. A red conglomerate occurs here in Hilton beck, a granite vein in Dufton pike, and a greenstone dyke is described by Dr. Buckland along the line of the disruption.

The general character of the declinations along this remarkable fault is very simple, a long and moderate slope from it toward the east, and a violent and short dip from it to the west. The steeply inclined beds on the west form a narrow, but not visibly continuous band, called in several parts 'the edge beds:' and these are often described as thrown into a 'vertical' position. In fact they are nearly or quite vertical where seen in the great escarpment under Cross fell, Dun fell, and Scordale head; they are also nearly or quite vertical in crossing Dentdale, along Barbon beck, and at Barbon chapel; but a more general condition of these beds is that of a dip from the axis of disruption, varying between 30° and 80°, and so related to upheaved slate rocks, unconformable red sandstone, and accumulated detritus, that only a small portion of the overthrown rocks can be clearly seen, and that only at distant points.

As before observed, the elevated region on the east rises moderately to the fault: yet it is a general truth that this rise of the beds becomes continually more and more considerable as we approach the axis, and where good sections can be consulted, it is found that the eastern beds turn up to the fault for a short distance very abruptly, and that there is really an anticlinal axis under some parts of the Penine escarpment.

The appearances presented by this great line of dislocation are no where more complicated than in the country between Brough and Ravenstonedale, where its direction changes. About Brough (in the stream from the direction of Lunedale, and on the road to Bowes and Tan hill) ridges of vertical and inclined strata run in various directions; apparently under the triple influence of the Cross fell and Kirby Stephen branches of the Penine fault, and the independent dislocation of Lunedale.

About Kirby Stephen also the direction of the dislocated strata is various, and, as at Brough, the beds are often vertical or dipping steeply from the elevated region on the east.

In the lower part of Mallerstang dale where the strike of the beds is north-east and south-west, meeting the Cross fell branch at an angle of 110°, the limestone ridges cross the Eden from the west, to the hill called Bells on the east, dipping 60°, 80°, or 90°, according to the distance from the axis of disturbance. Both the north-west and south-east dips are very evident on the right bank of Eden, proving a real anticlinal axis; on the left bank the water crosses a long section of the lower lime stones and incumbent shales, dipping south-east 60° to 80°. This excessive steepness of dip belongs only to a narrow breadth from the axis, and is seen only in the lower limestone series. The same anticlinal ridge is traced between Nateby and Swaledale head; the upper limestones of Swaledale head dip rapidly south-east; and those toward Nateby fall steeply to the north-west.

In the same district some red limestone beds (low in the series of limestone) range north and south and dip east 10° on the hill near Hungerstone hall. The brockram or equivalent of magnesian conglomerate ranges also north and south. South of Kirby Stephen an east and west ridge joins the Penine fault from the Cumbrian district, and adds to the complication. *(See Diag. No. 3.)*

The direction of the main dislocation becomes south by west from Wild Boar fell to Graygarth, where it turns again to the east. From Brough to near Kirby Lonsdale the western side of the fault is commonly marked by vertical or highly inclined limestone, called the 'edge beds.'

The lower end of Garsdale shews distinctly the fact of the beds on the east or elevated side of the Penine region being thrown into highly angular positions, close to the fault. On entering this valley from Sedbergh we find the beds of grauwacke dipping north-west 10°, 15°.—Limestone ridges (of the lower series) appear crossing the bed of the river in lines nearly north and south, and dipping 80°, 70°, 60°, 40°, to the east, according to their proximity to the axis of the fault. In the fells to the east the upper or Yoredale limestones appear nearly level; the lower limestones also become nearly horizontal as they recede from the plane of dislocation.

The appearances between Dent and Kirby Lonsdale are highly curious. In passing along the road from Dent to Barbon, we proceed chiefly on the overthrown beds west of the Penine fault; and these are seen in several places vertical, and in others dipping 60° west, so as to come, apparently endways, in contact with a line of grauwacke hills rising a thousand and more feet above the valley. The water courses in which beds sloping west are best seen, also shew higher up the beds on the eastern side of the fault. In some cases these are found to dip east, about 30°, in others they lie level. The valley in which the road runs follows the edge beds for some miles, but then turns at right angles through the slate ridge on the west. Having passed

this, it encounters directly, and crosses, another ridge of vertical limestone, which continues for some distance to the south, parallel to the main line of the fault which proceeds down Leck beck.

The ridge of grauwacke forming Casterton fells is thus bordered on both sides by limestone, ranging north and south, and on arriving at Kirby Lonsdale the Penine fault suddenly turns to the E. S. E., and receives the name of the Craven Fault. *(See Diag. No. 1.)*

The general character of this great branch of the Penine dislocation is a downthrow on the southern side of one thousand, two thousand or more feet, according to the locality, accomplished by one or two faults. This great southward drop of the beds forms the remarkable valley called Lonsdale, which ends on a low summit of drainage, corresponding exactly to that on the line of the great northern fault at Brampton. *(See Section No. 1.)*

On the north of the Craven faults the limestone holds a high and level course from Graygarth fell to Wharfedale; south of it from the same point to beyond Ribblesdale is the subjacent parallel narrow band of slate rocks, whose divisional surfaces range in *this same direction;* then follows on the south an interrupted belt of the same limestone, depressed some hundreds of feet and dipping south in most places very steeply; south of this is another great line of fault, which is very conspicuous from Wharfedale to Giggleswick scar, and is probably continuous by Clapham and Ingleton; in the Burton coalfield the strata dip toward the slate ridge. Along the line of the northern of these faults a remarkable greenstone dyke is seen at Ingleton, accompanied by contorted slate, &c.

The extent of the dislocations caused by these faults varies. The northern drop is about three hundred feet. The total depression under Ingleborough arising from two slips and one very steep dip, is not less than three thousand feet, about Settle one thousand, and it diminishes toward Grassington, where numerous other dislocations confuse but do not destroy its effects.

The general condition of the beds on the line of the northern of the two parallel Craven faults is closely analogous to that which has been described on the line of the Penine fault. The limestone beds are usually removed from the axis of disturbance; enough however can be seen to assure us that while the elevated beds rise slightly to the fault, the depressed beds fall steeply to the south: they are no where vertical, and the angle of their inclination to the horizon continually diminishes as we proceed to the east, so that in Ribblesdale it is less steep than in Clapham dale and Ingleton dale, and on Malham moors the depressed beds are nearly level.

In fact from the point where the southern fault becomes distinct in Giggleswick scar, *it* appears to assume the character of the northern line, so far as to cause a very violent southward dip of the depressed beds; and in Feizer, Kirby fell, and Malham moors, the elevated beds rise to this fault.

At Giggleswick the level lower limestone is opposed on the line of the southern fault to the inclined millstone grit of Ingleborough, indicating a slip of one thousand feet; the same is the case at Ryeloaf and Brown hill.

At Malham calamine has been long worked in a vein parallel to the line of the great southern fault; Malham Cove scar is also parallel to it, and in this part of the country it is seen to hade or underlay *to the south,* conformably to the general law. The valley from Malham downwards is full of dislocations and varying dips, (especially at Kirby, Malham, where the beds range E. by N. and dip 40° N.) the general result being a dip of the depressed beds from the great fault southwards for one mile, then a rise in the same direction, so as to expose a considerable tract of upper Craven limestone on both sides of the Aire about Calton, Otterburn, Coniston, and Eshton, thus connecting them with the range of limestone by Flasby, Rylstone, and Burnsall.

Malham Tarn is situated on the line of the northern slip, here three

hundred feet, under the bold escarpment; much alluvial matter lies about its borders, and its waters have formerly been more extensive; the hollow caused by the slip reaches Wharfedale between Kilnsea and Threshfield, and is obscurely continued across the Grassington moors, where it falls into another system of dislocations, having had a clear and uninterrupted course from the coast of Northumberland to Wharfedale, one hundred and thirty miles.

In this long course its bearings have varied much; the line from Cullercoats to Brampton has three principal directions,—W. N. W. near the sea, W. S. W. across the Tyne, and W. along this valley to Brampton: thence to Brough nearly S. E. by S.—Brough to Wild Boar fell nearly S. W.—and thence to Graygarth S. S. W. From Graygarth to Wharfedale E. S. E. turning however more to the eastward as it approaches the Wharfe.

THE RIBBLESDALE SYSTEM.

The country to the S. W. of the great Craven fault, which ranges from Kirby Lonsdale by Settle toward Pateley bridge, has its own system of disturbances chiefly in a direction from N. E. to S. W. Anticlinal lines of convulsion in this direction traverse the country from Lothersdale by Pendle hill, Whalley, and Blackburn; some pass through the district of Whitewell and the trough of Bolland, and others through the centre of the Craven depression. The most striking features of this part of Craven, and the adjacent tracts, depend on these N. E. axes of movements, as the grit summits of Long Ridge, the limestone valley of Bolland, Pendle hill, Padiham heights, the Burnley coalfield, the limestone valleys of Lothersdale, Skipton, and Cracoe. It is remarkable that in the northern part of their range these dislocations change their direction and turn E. and W., so as to approximate to the line of the great Craven faults. Thus in the Skipton valley the limestone ridge bends round and turns due E. across the Wharfe,—from Flasby the limestone swell in like manner turns east across the same river to Greenhow hill. While the

northern system of dislocations is characterized throughout by sudden and violent fracture and partial displacement, the southern consists wholly of steep anticlinal ridges, generally bent into continuity over the axis, so as to cause a system of parallel undulations and contortions for twenty miles in breadth between Colne and Lancaster. Its south-westward extension, as indicated by the ranges of the Lancashire coal tracts, is about fifty miles; further prolonged it would cross the N. N. W. line of elevation in the vale of Clwydd, and nearly coincide with the axis of North Wales. From about Burnley proceeds in a direction S. S. E. the great range of dislocation which reaches the Peak of Derby and throws off on the east the Yorkshire coalfield, and on the west parts of the Lancashire and Cheshire coal tracts.

The diagram (No. 14) may be usefully consulted for the relation of these various disturbances.

FAULTS AND MINERAL VEINS.

We may now proceed to trace the relations of the minor dislocations included between the great branches of these systems of disturbance.

The great area included between the Penine fault and the magnesian limestone terrace is not so much disturbed by faults as the violent convulsion of its borders might lead us to imagine. The mining tracts of Teesdale, Swaledale, Wharfedale, and Greenhow hill, are indeed much convulsed, but it is certainly true that we may trace for many miles along the slopes of Wensleydale, Garsdale, Coverdale, and on the sides of Cam fell, Ingleborough, and Wharnside, particular beds of rock not at all disturbed by convulsions. In most cases the great dales and lesser valleys appear to have been marked out by dislocations specially determining their line, or generally influencing the direction of their descent. Professor Sedgwick admits a great fault as ranging down Teesdale, Lunedale is on the line of a dislocation,

Swaledale is nearly parallel to the Auldgang and other east and west lead veins, a small fault perhaps passes down Wensleydale, a remarkable dislocation ranges east and west along the head waters of the Nid, and a great depression about Pateley invites its course afterwards to the south-east. But the upper parts of Wharfedale and Ribblesdale appear wholly independent of this kind of influence, and in their further progress they hold their courses across the lines of disturbance.

The dislocations in Teesdale are perhaps the most remarkable and well traced of those which occur in the mountain limestone district of Yorkshire. The Burtree ford dyke, which passes from the head of Weardale in Durham by Langdon common and east of Cronkley scar, causes in the northern part of its course, according to Mr. Forster, a downthrow of eighty fathoms to the east: by my measures in 1833, it seems to be sixty or seventy fathoms along the Aldstone moor road: and it is probably nearly as much on the east side of Widdybank scar and Cronkley fell; it is supposed to extend to Lune head.

The Teesdale fault first noticed by Professor Sedgwick, ranges from Eggleston by Lonton as far as the High force, and appears to be as much a case of a very steep dip to the north as a real fault; at least such is the probable conclusion from the phenomena visible about Unthank, Holwick, and Winch bridge. At Middleton the difference of level on opposite sides of the valley appears to be some hundreds of feet; between Winch bridge and Holwick scars about one hundred feet; but the beds dipping steeply to the north the final result may be doubled or trebled. Its course is not at all clear in the upper part of the valley; it may be conjectured to join the Burtree ford dyke a few miles above the High force, and on the north side of Teesdale.

Besides these, I think there is another considerable dislocation passing north-east and south-west along Maize beck, between Mickle fell and Birkdale, not far from Caldron snout, having a downthrow to the north-west; there is also a very decided dislocation ranging up

Lunedale, (independent of slight throws accompanying the Whin dyke of Greengate and Wommersgill;) which throws down to the south so greatly as to alter entirely the character of the whole region. North of the dale, the whole Yoredale series may be traced, in ascending to the tops of the fells; in places also the Tyne bottom limestone (it is supposed) lies over the Whin sill, (which however is in extreme confusion at Saddlebow); but south of this river the country is formed of the grits, plates, and cherty beds of the millstone grit series. So great is the effect of this dislocation, and the steep dips to the south connected with it, that the difference of elevation of analogous beds at some distance from the fault is fully one thousand feet.

It is remarkable, as a general and leading fact with respect to mineral veins, and by consequence to the faults which almost universally accompany them in this district, that their predominant direction is north of east. The *greatest number* of mineral veins occurs in this direction; the greatest *quantity* of metallic ores is obtained from veins running east and west. This indeed is a general fact in geology, for east and west courses of veins are the normal directions for great part of Europe whatever be the age and nature of the rock including them. But even in Yorkshire other directions are noticeable which it will be instructive to survey.

The most perfect example of east and west dislocations in Yorkshire occurs in Swaledale and Arkendale, parallel to Yoredale, Swaledale, and Gretadale. The celebrated Auld Gang lead mines, and many others on either hand, are established principally upon the great vein called Fryerfold, which ranges from Swaledale head down the north side of the valley toward Gilling and Middleton Tyas. Its whole course, probably, is continuous from the latter locality to Wild Boar fell, a distance of thirty miles, in a constant direction a little south of west. In driving the Hard level at the Auld Gang mines, on the south side of this great or master vein, six veins and strings were cut through all nearly parallel to it. Two of these almost absolutely vertical were

accompanied by little or no dislocation. The great vein and that most remote from it, throw down to the south twelve or fifteen fathoms; the remaining two veins throw down to the north. The southernmost vein is remarkable because both the depressed and elevated beds curve upwards towards the fault. *(See Diag. No. 18.)*

The Marl becks and other veins in Teesdale range mostly east and west, and the same prevalent direction (a little north of east) is noticed in the mines of Weardale, Aldstone moor, and Derwent.

Mr. Forster in his account of the mines of Aldstone moor and the neighbouring tracts, has the same observation as to the predominance of east and west veins. 'The fissures or veins of the mines in Weardale, Allendale, and Aldstone moor, mostly extend from east to west: or more properly, one end of the vein points west and by south, while the other tends east and by north: although there are other veins running nearly north and south, commonly called *cross veins:* and it must be remarked that these cross veins have very rarely been found so productive of metallic ores as the others, excepting when the right running veins and the cross veins intersect, in which case the cross veins generally carry ore for some distance from the place of intersection, but very seldom in any other stratum than limestone and especially the great limestone of Aldstone moor.'

Mr. Sopwith observes of this same country 'most veins in the mining district preserve a tolerably direct course for a considerable distance, some indeed for several miles. They are commonly designated *veins, cross veins, and quarter point veins.* The former are sometimes called right veins, their course being E. and W. or a little N. of E. and S. of W. Those which have a bearing nearly N. and S. are called *cross veins.* The few veins which have a bearing between these are called *quarter point veins.*'

The prevalence of certain directions in the fissures of veins being established, we may next inquire what relation is borne by the plane

of dislocation to the elevated and depressed portions of the strata, or what is the relation of 'hade and throw'—and whether there be any connexion between the dip of strata and direction of hade and throw. *(See Diag. No. 15.)*

First.—Relation of 'hade and throw.' A general law of this relation has been long known to miners and colliers, to which in secondary strata few exceptions have been found. It may be thus expressed; the 'slip,' or plane of dislocation hades, dips, underlays, or is inclined to the vertical so as to pass under the depressed portion of the strata which are displaced. *(See Diag. No. 16.)*

Thus A is the downcast or depressed set of strata and B the upcast V. v. the plane of dislocation, inclined from v. v.' the vertical, so as to dip under the downcast side. The contrary case *which* in some hundred instances of dislocation, *I have never seen*, would be as in the next diagram *(No. 17.)*

In mining language the beds are highest on the ledger (lower) side of the vein, and lowest on the hanger (upper) side.

The hade of veins and faults varies in strata of different quality as limestone, sandstone, plate, &c., for it is most nearly vertical in the hardest and most solid rock as limestone, hard gritstone, but slopes most from the vertical ('hades most') in plate and soft alternations.

The width of the fissures varies in the same manner, being open in limestone, partially contracted in gritstone, but much reduced in breadth in plate. These are important facts.

Secondly. Relation of the throw of veins to the dip of the strata.

In particular districts the veins throw the beds up or down more in one direction than other, and there appears some law of the relation of dip and throw. Mr. Forster observes that the east and west veins of Weardale generally throw the north cheek up; and

hade south, most of those in Allendale and Aldstone moor throw the south cheek up and hade north. In these latter tracts the dip of the strata is northward, and thus dip, hade, and throw coincide.

In the Swaledale mining district the dip of the strata across the veins is very inconsiderable either way, and the throws of the beds are partly north and partly south.

In the Grassington mining field the veins range north-west and south-east, and east and west (the former are the strongest and best veins), they nearly all throw down to the south, and hade and underlay in the same direction, which is also the line of principal dip of the strata. Thus dip, hade, and throw coincide to depress the beds on the southward.

In the Greenhow mining field, which indeed joins with that of Grassington into one great mineral district, the prevalent directions are W. N. W. and North-west as at Grassington; the veins go through and cross the axis of elevation formerly described as ranging E. by N. One of the veins undergoes a change of direction when it meets the axis from E. S. E. to South-east, so as to cross it more nearly at right angles.

From these observations we learn that in parts of the Penine region differently related to the great axes of convulsion, the prevalent directions of the mineral veins are different. Both east and west and north and south veins prevail in the northern region influenced by the east and west fault of Tynedale and the north and south fault of Crossfell: at a greater distance from the Tynedale fault, the veins in Swaledale almost all range E. by N.: near the *local east and west axis of elevation* of Greenhow the direction of the veins is complicated thereby so as to assume a tendency to cross it rectangularly.

If then we could examine this question in a district where no *great faults* but only *anticlinal axes* occurred, we might expect to find a deter-

minate relation of veins to these axes different from that which they bear to *great faults*. Such a case occurs in the country occupied by the Ribblesdale system, for the many parallel anticlinals which compose it are little influenced by great faults. *Few mineral veins* are worked in these tracts—but both in the Skipton ridge, and the Lothersdale valley of elevation, we have several metalliferous veins running *across* the axis of dislocation, and in the western anticlinal of Bolland one running *along* the axis.

Again, it is parallel to the Craven fault that the calamine mine of Malham moors has been worked, and in the same country other veins, nearly in the same direction, range over the limestone hills of Arncliffe and Hardflask.

As a negative instance the paucity of mineral veins in the great undisturbed mountain limestone of Ireland is of value.

From all these considerations it is apparent that the local abundance of mineral veins is very much in proportion to the proximity of great lines of fault, and anticlinal elevation, and that their east and west direction, though very predominant, is yet in the Penine region variable in relation to such faults. Where the Cross fell fault ranges N. N. W., it is rectangled to the right running veins and parallel to the cross veins; where it ranges S. S. W. it is still rectangled to the majority of the veins; near the east and west Tynedale fault, and for a great distance south, the veins range east and west; near the E. S. E. Craven fault many of the veins range E. S. E. and W. N. W. Fewer veins depend on anticlinal axes of elevation, and most of them *cross* these axes.

The veins in Flintshire are mostly a little north of east and a little west of north—those of Derbyshire are in the northern parts N. N. E. and in the southern parts S. S. E. Are the Flintshire and North Derbyshire veins dependent on the N. W. faults and axes of elevation, and the South Derbyshire veins parallel to the southern limestone fault?

We may next consider the relation of these systems of dislocations and their dependent faults and veins to each other.

The Ribblesdale system, in all the northern parts, appears to pursue its rectangled direction toward the Craven fault till it comes so near as to sink entirely under its influence, and lose all characteristic feature, in a general dip toward that fault. This fully appears from the facts known with regard to the Ingleton coalfield.

If we conceive all the country south of that fault to have undergone a vast relative depression, and that at right angles to the line of the fault many parallel undulations of the strata sprung out, which arrived at a maximum of curvature a short distance from the fault, we shall have a right notion of the case.

In the eastern part of the country, where the influence of the Craven fault is less, these undulations assume near that fault more and more of its direction, till, the fault turning more northward and these undulations bending southward, they finally coincide in the limestone ridge of Greenhow hill, to which the Skipton anticlinal is parallel, and from which that of Lothersdale deviates less than those of Ribblesdale and Bolland.

It deserves remark, that all the anticlinal axes are subject to cross rolls or undulations, of considerable amount; so as to break up each long axis into several short *oval quaquaversal elevations*, the very case so much contested by some geologists, and on which Von Buch's hypothesis of the origin of volcanic vents is founded. The Greenhow ridge E. by N. is crossed by two and terminated by two other such transverse undulations ranging nearly north-east and south-west, and north and south: the Skipton ridge is in the same way broken into two great portions besides smaller dismemberments: we see the same thing in the Lothersdale axis, and in the Bolland elevations, and it is the general cause of the innumerable insulated hills of the lower parts of Craven.—Is it not probable that these *cross undulations* are posterior to the main line which they *interrupt?*

Veins which cross.

In the northernmost part of the Penine region, the east and west veins are commonly divided by the north and south veins, which therefore receive the name of Cross Courses. The same thing happens in Cornwall, and indeed *generally*. Particular phenomena happen at their junction, which involve the question of the relative epoch of these veins in some obscurity. Werner has been almost universally followed, in asserting the cross veins to be of later origin than the others, because *they cut through them*. That they are of *different date* is highly probable from the difference of their contents.

The following are some of the most important facts on this subject, observed in the North of England.

The north and south veins divide those running east and west, in almost every instance, but some exceptions occur. The divided vein, if it hades and the vertical throw of the cross vein be considerable, will be displaced, so that its divided parts remain parallel but not coincident planes, and viewed in a horizontal section *appear* to have suffered *lateral movement*. Two veins hading oppositely may thus *appear* to be shifted in opposite horizontal directions, as in the drawing given by Mr. Forster, p. 205.

The divided vein sometimes undergoes a curvature on one side near the cross vein; sometimes it is split or ramified into portions on one side; in one instance the throw changes on the different sides of the cross vein; in some examples the right vein ends in the cross vein.

The cross vein itself is little affected by the circumstance of passing through the others; it is subject to the same general law of hade and throw, and the lateral shift which it sometimes occasions in other veins to a great extent (one hundred and fifty feet) is according to the same analogy. These veins are occasionally productive of metal where they cross the right veins.

Besides cross veins, right running and quarterpoint veins, are (backs) or joints of the rock, which occasionally turn aside *all* the veins and always according to the law of the angles already explained.

Dynamical relations of disturbed Strata.

Dependence of direction on structure.—We may now consider the dependence of the great phenomena of dislocated strata on dynamical conditions and geological periods. It is already apparent that the direction of the joints of rocks is a phenomenon of more general occurrence than the dislocations, dependent on more pervading and uniform agency. The almost perfect constancy of their directions, amidst all the variations of the faults and breaks of a dislocated district, leaves no doubt of their independence of these; but the correspondence observable in several instances of the direction of the dislocations and fissures opens a new view of the matter. The stratified masses, divided in their separate beds into characteristic structures, and traversed through whole formations by long and continuous fissures crossing in two principal directions, presented lines and points of least resistance, which would yield variously to the impulse of any sufficient pressure upon their planes. Such pressure, acting from below or from above, would necessarily break at least partially the continuity of the extended strata, by raising or depressing certain parts: if the principal mass of the strata displaced had very close joints or were imperfectly consolidated, (as laminated argillaceous rocks), they might be uplifted or depressed in great waves or small curved ridges and furrows, (the general character of the Ribblesdale system): if the rocks were much divided by open joints, and generally consolidated, the displacements happening along the planes of least resistance would depend for their direction on the relations of the natural joints and fissures to the direction of the force.

If a great force were supposed to be exerted against *a small area*, the effect would be a *conical elevation or depression modified* according to the influence of one or two systems of yielding fissures. One such system of yielding fissures would elongate the conical displacement

into an elliptical section; two such systems would probably produce the curious phenomenon of an elliptical elevation or depression, corresponding to the (locally) predominant set of joints, bounded by contrary depressions or elevations, parallel to the other set. This remarkable result is illustrated in the whole Ribblesdale system, at Greenhow hill, &c.

Were the elevating or depressing force perpendicular to the planes of stratification and applied in a *particular line*, the stratified masses if uniformly thick, and yielding with general uniformity along this line, would occasion an anticlinal ridge or a synclinal trough; and parallel breaks and bends would be occasioned, their distances, numbers, and extent depending on the character of the joints, the thickness and elasticity of the stratified masses, and the degree of force employed.

Were such forces applied in a line to extended masses of unequal resistance, the effect might be in one part an anticlinal, in another a synclinal axis, in a third a great fault, and the lines might not be straight. (The same effects might happen at the boundary of a large elevated or depressed district.)

Were the forces applied uniformly to a *great area* of horizontal rocks, uniformly resisting, axes of displacement rectangulated to one another but of indeterminate direction must happen;—if there were one system of open joints, this would determine a primary axis of displacement, and by consequence secondary axes also, for as the primary displacement is supposed limited, any further fracture not parallel to it would be most easily effected along the shortest line from one of its parallels to another. If in addition we suppose a second system of joints this must greatly influence the lines of secondary fracture: unequal loading of the strata might change the axes of primary and secondary elevation or depression into a great fault and cause them to bend or zigzag in their course.

It appears then that the direction and character of displacement

of the strata, depend on the mode of application of the force, the jointed structure of the rocks, and their condition of load or pressure. According as the impulse and resistance are uniform, or determined to particular directions, the effects must vary, accordingly, and from these we may infer the former.

The Ribblesdale system indicates linear impulse, in a north-east and south-west direction, the Penine system a general impulse determined to various lines, by the jointed structure and unequal weighting of the rocks: the Greenhow system, placed at the intersection of the Ribblesdale and Penine displacements, has the character of impulse at a point, or interrupted line.

Thus far successful let us next inquire into the cause of the remarkable and almost constant relation of displacing and displaced planes. This is not a local but a general fact, liable to exceptions in particular districts, but of great theoretical importance. It appears a natural consequence of the dynamical conditions of the problem. *(See Diag. No.* 19.*)* Any extended mass of horizontal strata, a b c, yielding to a mechanical force normal to the surface must break at right angles d d, (i. e. vertically) or at unequal angles, x x. If the former case there is no reason â priori why one part should be lifted or depressed more than another, (many vertical veins are thus circumstanced and have no throw.) If the latter, and one side be relatively elevated, as A or B, the part b x x being unsupported can not be raised from A at all, if the rock be much jointed, or at all events without some of its parts being unsupported and falling so as to produce fissures and and veins more or less inclined in confusion toward x x; A on the contrary may be lifted and the beds of B retain their order and regularity, the lateral pressure being transferred horizontally to close up the parallel joints near the throw.

It follows that displacing planes which intersect strata at other than right angles, and are not accompanied by great confusion on the hanger (upper) side, must in general dip under the depressed por-

tion of the strata—which is the practical law of miners and colliers, and which I have verified by a multitude of examples in the superior orders of strata. The same reasoning would apply to the case of intersecting planes, one of which displaces the other, in a horizontal direction, but most of these are really explicable as cases of vertical movement of *inclined planes;* the apparent horizontal translation being proportioned in amount to the angle of inclination from the vertical of the plane displaced and the extent of its vertical displacement, and determined in direction by the direction of its dip.

The variation of the hade of a plane of displacement, in strata of different nature, is to be explained by considering that in determining the direction of the parts of this plane, the *strata of* least continuity or *least resistance* have the greatest influence, while those of most continuity must yield to the impulse of the others. While limestone completely jointed with wide joints yields in vertical planes, and gritstone partially so, laminated clays with close joints must often be found to yield obliquely. Such are the facts, and they are the more constantly observed in limestone tracts, because the laminated plates there occuring have oblique joints as well as vertical ones.

The relation of throw of fissure and dip of strata is perhaps not a fact of sufficient generality to be made the basis of reasoning, yet if we consider that the angular elevation (producing dip) of the strata, the displacement of portions of them, and the corresponding hade of the vein, are all effects of the same action, we shall not be surprised to find these effects all happening in *the same direction*, which is the most general condition observed.

Geological Periods.

We come finally to examine a question, which has of late years risen to the highest importance, viz. the geological period of these disturbing movements. There is but one process for its solution: we must see what strata *are*, and what strata, under similar circumstances, are *not* dislocated. The former gives the minimum, the latter informs

us of the maximum of geological antiquity; between these *limits of error*, the events certainly happened. The Tynedale branch of the Penine fault, divides the magnesian limestone range at Cullercoats, it therefore happened not earlier than the deposit of that rock; it does not we believe dislocate the red sandstone of the plain of Carlisle; thus its date is supposed to be accurately fixed.

The Penine fault from Brampton to Kirby Lonsdale no where dislocates the new red sandstone, (the magnesian conglomerate of Kirby Stephen is not in general dislocated on its line, one case occurs at Brough.) It disturbs the slate rocks, the whole limestone and millstone grit series, and thus *may be of* the same age as the Tynedale fault, can not be more recent, and can not differ widely from it.

The Craven branch of this system dislocates slate, limestone, gritstone, and coal measures; the magnesian conglomerate of West Houses is circumstanced nearly as that of Kirby Stephen; this fault seems therefore to be of the same age as the Penine fault, and it is extremely probable, from the remarkable continuity of the whole range and the analogy of direction as well as extent of dislocation, that if not all of one epoch—all the parts of this great fault were produced after the coal and during the earlier part of the saliferous period.

The Ribblesdale system is of the same or nearly the same age, for it dislocates limestone, gritstone, and coal, and its prolongation in Lancashire, toward Ormskirk, does not break up any part of the red sandstone. The Derbyshire system is of the same age, and so is that of the vale of Clwydd.

The view previously advanced of the dependence of the great faults and mineral veins on the Penine fault and Ribblesdale axes of elevation leaves no room for doubt as to these being of the same dates generally. The faults of the coal district of Derbyshire, Yorkshire, Durham, and Northumberland, are mostly anterior both to the new red sandstone, magnesian limestone, and Rothetodteliegende, and if these like

the mineral veins depend on the great axes of disturbance, we shall be forced to conclude that the Craven and Penine faults are older than the Tynedale branch; if there be no such dependence, they *may* all be posterior to many of the faults of the coal system.

The dislocation of the magnesian conglomerate along the line of the Penine fault does certainly occur, but only in a small space near Brough, where the line of the fault varies from S. S. E. to S. W. In the country near Brough the dislocation of magnesian limestone beds ranges north 10° west, (nearly parallel to the Cross fell fault,) and these beds dip 70° and 80° west; but that district is so confused by many minor axes of convulsion that the effects of different periods may be undistinguishable. A suspicion might arise that this dislocation, though on the line of the fault, is not of the same age as the other parts, because of its bearing north 10° west, and because of its apparent independence of the carboniferous limestone; yet as here the 'edge beds' begin and continue hence to join the Craven fault, that must not be hastily adopted.

To doubt the contemporaneity of the whole extent of the Tynedale fault, would be to resign all arguments on the subject of geological dates of convulsion, for the direction and amount of throw and hade and the condition of the neighbouring strata give this dyke, notwithstanding its zigzag course, a most determinate character.

If now we change our view and consider the question in a more general aspect, connecting the Penine, Ribblesdale, and Derbyshire systems of dislocation, and *attributing to each the leading features* of the corresponding coal tracts, we shall be led positively to date these disturbances after all the coal measures and before all the saliferous rocks; for it is undoubted that the Lancashire red sandstones and magnesian limestone are not conformable to the coal, any more than the magnesian limestone and red sandstones of Nottingham, Derbyshire, Yorkshire, and Durham. We must however except the southern

border of the Derbyshire and Nottinghamshire coal tract which, at least in places, appears to have suffered disturbance since the red sandstone epoch.

Upon the whole then from general considerations we find it *probable* that the great north and south system of faults from Brampton to Derbyshire was occasioned before the production of any beds connected with the new red sandstone;—particular examinations prove the northernmost (Tynedale) branch and the southernmost (border of Derbyshire coalfield) branch from this system, both running eastward, to have been disturbed *during* the new red sandstone period; there is *no sufficient proof* on the line of the Cross fell or Craven faults of their exact date, yet the general unconformity of the whole red sandstone system, the generally horizontal or slightly inclined surfaces of the magnesian conglomerate at Kirby Stephen and Bela bridge, as well as at Westhouses near Ingleton, lead to the conclusion that these faults were anterior to the magnesian rock. The only objection to this conclusion is derived from a limited dislocation of the conglomerate near Brough, where however it is not in conformity of disturbance with the carboniferous limestone. Upon the whole then, I venture to adopt the conclusion that the Penine and Craven faults, as well as the Ribblesdale and Derbyshire disturbances, preceded the magnesian limestone epoch, but the Tynedale fault and some other considerable dislocations are of somewhat later date. It is however impossible to close the discussion without expressing the surprise which I feel that such a complicated problem as that of the age of a great system of convulsion should ever be thought easy of solution.

Faults in different directions.

The age of the great systems of disturbance affecting the carboniferous series of the North of England thus determined, we may attend to a minor but curious question as to the discovery of any differences of age among the faults depending on these systems. When veins or faults intersect and one displaces another, is there any difference of age, and if so which is the older?

The popular opinion on this subject, the one almost universal amongst practical men, can not be better expressed than in the words of Werner. (On Veins, Trans. p. 51.)

'Every vein which intersects another is newer than the one traversed, and is of later formation than all those which it traverses: of course the oldest vein is traversed by all those that are of a posterior formation, and the newer veins always cross those that are older.' Werner elsewhere delivers his sentiments on the mode of this intersection, noticing the displacements, and changes of the condition of the new and old vein at their intersection. He does not seem to have thought the difficulties attending this latter subject of such importance as to deserve special discussion; but it is clear he was perfectly acquainted with them, and thought his hypothesis comprehended them.

Admitting, what in the stratified country of the North of England can never be doubted, that the metalliferous deposits were introduced into open fissures of the rocks, the operations, according to the Wernerian doctrine, may be thus described. First a dislocation happens along an east and west fissure generally hading in one direction in all parts of its length and *throwing* down in one direction, but sometimes changing both throw and hade at different parts; this fissure is filled by the sparry and metallic substances; subsequently it is broken across and a new fissure formed, which afterwards is filled with substances generally different from those in the earlier veins.

The strong argument in favour of this view is the *equal dislocation* occasioned by the cross vein on both sides of the divided vein: it affects equally the elevated and depressed strata bordering that vein, which could hardly be the case if the dislocations of that divided vein had not been accomplished, the vein filled, and the whole mass coherent.

It seems hardly possible *in a stratified country* to elude the force of this clear argument: but let us suppose the contrary, viz. that the cross vein is the oldest: upon this view the fissure of that vein

having been filled, and its accompanying displacement fixed, fresh fractures took place transversely, which displaced the strata along certain planes parallel or coincident on both sides of the cross vein, with equal dislocations in the same direction, yet did not traverse that vein at all, but caused a general sliding along its planes. This complicated hypothesis contrasts very unfavourably with the simplicity of the former popular opinion, and involves more than one improbability.

Yet there are particular phenomena occasionally occurring in a mining district, at the intersection of veins, which are somewhat embarrassing on either view. For it sometimes, but not often, happens that a divided vein is *ramified on one side* of the cross vein,—that another is continued beyond the intersection for some distance *in a new plane*, and then resumes its old course,—that others *change their throw* at a cross course.

The ramifying of a vein on one side of a cross course, can perhaps only be explained upon the popular view by supposing it an *accidental coincidence;* veins are often ramified, and cross courses are frequent; such coincidences then ought not to be thought surprising. Werner appears to have thought that such cases implied openness of the divided fissure at the time of the formation of the cross vein.

The continuation of a vein in a new plane, for a short distance, is usually accompanied by a considerable lateral displacement, not explicable as a case of vertical dislocation of an inclined plane; such an oblique translation of great masses of strata may be expected to produce other singular phenomena.

The change of throw at a cross course, if not an accidental coincidence, can only be explained by admitting for *such particular vein*, a displacement contemporaneous with the cross course, or posterior to it. The instance given by Mr. Forster is equally compatible with either opinion, as may be seen by turning his plan into a vertical section.

The only other view remaining to be noticed is the opinion now prevalent in Cornwall, that there is no criterion of age to be derived from the intersections of veins; and in fact that these can not be proved to be of different age from the rock. There is always more difficulty in demonstrating this difference in rocks which, like the slates of Cornwall, are more remarkable for symmetrical than stratified structure. But it can be proved even in these instances that most of the veins occupy fissures which are of date subsequent to the rock; this granted, the *relative* date of veins which meet follows the same laws as those in other districts.

Upon the whole we may admit the greater number of cross veins to be of later date than the divided veins, at least in the limestone tracts; some exceptions may and probably do occur, but more and better arguments are required to prove it than any yet adduced. The cross courses in Yorkshire and Tynedale run generally about N. N. W., parallel to the Cross fell faults. This however may not be more than an accidental relation, for N. N. W. fissures are characteristic all over Yorkshire and frequent in the bordering counties. It is more probable that the range of the Cross fell fault and that of the cross veins of the North of England are dependent on this constant structure of rocks, which appears to be the primary phenomenon.

In the same manner the east and west veins are coincident with a system of fissures in limestone, which probably guided in part the Tynedale fault; the Greenhow veins appear related to E. S. E. courses, because the fissile structure of the subjacent slates is developed in that direction, and has permitted two parallel dislocations to happen along these divisional planes.

Coalfield of Lonsdale.

The history of the mountain limestone district of Yorkshire would be incomplete without some notice of the remarkable coalfield which lies in the low valley of the Greta, at the foot of Ingleborough. In the natural order of events its description should have followed that

of the millstone grit; but, besides its connexion with the Craven fault, there are other points of view which have determined me to place it here. The most important of these is the occurrence of red sandstone over the coal. My own knowledge of this curious coalfield, obtained during my residence at Kirby Lonsdale, was not considerable, but for this full amends has been made by the ready aid of Mr. Hodgson of Lancaster, an eminent Surveyor, joint proprietor of the Burton coal tract, who has had the kindness to furnish me with accurate sections, and valuable observations concerning this coalfield and its relations to many coal deposits of the millstone grit series in North Lancashire, with which his professional and geological researches had made him well acquainted.

The situation of the Ingleton coal, in itself singular, is rendered doubly interesting to the geologist from its complete analogy to that of the Hartley burn coalfield on the south Tyne. Both of these little coal deposits are far detached from the large coal tracts to which they appear most related; both extend from east to west: both lie at the foot of a lofty escarpment of rocks much older than themselves; both rest on those same rocks sunk perpendicularly more than two thousand feet by dislocation. Certainly the first view of these situations would lead to the impression that the dislocations had happened before the deposition of the coal, for not a span breadth of deposits of the same age lies on any hill of the whole Penine region from Lonsdale to the valley of the Tyne, from Wharfedale to the Tees.—More exact inquiry reverses this opinion, and leads to important reflections on the cause of this extremely limited deposition of coal before the production of the Craven fault, or its almost total removal afterwards.

The section (No. 1,) from Burn moor in Bolland to Ingleborough, crossing the Ingleton and Burton coalfield, will sufficiently indicate the leading features of the deposits. It is not properly a basin, for its planes of stratification have scarcely any other dip than to the northeast; not according to their original position, but under the influence

of the Craven faults, both of which, it must be remembered, cause great relative depressions to the south. Though limited to the narrow area drawn on the map it has but one outcrop (to the south,) the northern edge being sunk to a great depth, and terminating against the plane of the south Craven fault. On the west, south, and east, the subjacent millstone grit rocks come to the surface, and it is seen beyond a doubt, especially on the south and south-west, that in this insulated spot, two thousand feet below the summit of Ingleborough, some of the lower strata of the far distant Lancashire and Yorkshire coalfields lie not only above the millstone grit of Penyghent and Ingleborough, but even above rocks usually several hundred feet higher than them in the scale of strata. The extent of the dislocation certainly amounts, near the side of the southern fault, to about three thousand feet. The following is the section of the Burton coal strata, as given to me by Mr. Hodgson.

		Feet.
Red marl		18
Red sandstone		30
Gray rock		24
White post		4
Soapstone (argillaceous)		6
COAL		1
Sill		
White rock		
Soapstone		36
COAL	1 foot	
Sill	4	
FOUR FEET COAL		4
Soapstone	4	
TWO FEET COAL	2	
Sill	4	
Crow coal rock ...	24	90
CROW COAL ..	1 6 or 1 8	
Soapstone	54	
SIX FOOT OR DEEP COAL		6 to 9 feet.
Black stone		3
Coal		2

At the Burton end of the field, the beds appear gradually to vanish, not cut off by any dyke or fault, but thinning off to nothing. Mr. Hodgson was particularly struck with this circumstance in the crow coal, while driving a level, for this bed gradually augmented in the level from a mere trace to eighteen inches, its usual thickness. The other thicker coals vary in the same manner and in the same direction. Hence it appears probable that toward the west the limits of this coalfield are nearly those of the original deposition.

The DEEP COAL is remarkable for having two thin layers of the finest light blue 'pipe-clay' running through it quite parallel, with surprising uniformity, and enclosing between them a thin layer of the purest 'jet or cannel coal.' Thus,

Soapstone.
Roof coal left until the pillars are removed.
Top coal.
Clay one foot thick.
'Jet coal' two or three inches.
Clay one foot.
Bottom coal.

Ironstone is found at Ingleton and Burton, in layers of nodules, and in huge blocks scattered through the 'eighteen yards soapstone,' some five or six yards in circumference, and containing in many cases remains of plants. Few specimens of shells have been found, but abundance of ferns, stellate and other plants, in the soapstone, especially where it approaches the deep coal. Charcoal and pyrites lie in the coal. The dip of the coal is north-east constantly.

It will be perceived that the uppermost strata of the Burton sinkings are marked red marl and red sandstone; these beds are laid conformably on the coal measures, but not interstratified with them: no red breccia like that of Westhouses, occurs in the pits. The crow coal rock assumes toward the outcrop a red colour; and it is remarkable that the miner's prejudice of 'red rock cutting off the coal' has extended even to this solitary basin.

From below, in the direction of Bolland, rises a thick series of millstone grits, and shales, inclosing near the bottom two coal seams, the lower one is from eighteen to thirty inches in thickness, and corresponds to that of Penyghent. This has been worked at Mewith, Bentham, Tatham, &c. None of the coal pits to this seam pass through red sandstones. The Mewith pits on the line of section give (according to Mr. Hodgson)

	Feet.	
Gritstone, rather coarse grained ...	24	
Plate or bluish shale	21	
Soapstone	5	
Grit rock, with thin partings of shale ...	36	
Plate, sometimes absent	5	6, and less.
Grit rock, roof of coal	6	and more.
COAL	1	6

One of the most extensive of these coal sections is that of Smear hall, near Wray, Lancashire, (given me by Mr. Hodgson.)

	Feet.	
Marl ... . } Shale with ironstone bands ... }	106	
Fine white rock	30	
Soft bands	1	
COAL (called Crow Coal)	0	2 to 9 inches.
Freestone post	6	
Black and rock layers	12	
COAL	1	6
Sill		
Fine rock	5	
Millstone grit, coarse grained	27	
Plate	210	

Here we see plainly the affinity to the Penyghent coal: the subjacent millstone grit is thin, and the Bolland shale is without any trace of the main limestone. The collieries of Farlton near Hornby, Tatham School near Lancaster, and Clints field near Low Bentham, agree almost exactly with the above section, but do not go below the coal.

The upper coal is not noticed at Clints field; the white rock above it is no where so fine grained as at Smear hall.

Without further details it is easily known from these sections combined, that the North Lancashire and Penyghent coals are identical; that the Ingleton coals are somewhat analogous to the lower coals of the Wigan and other coal deposits on the western side of the summit ridge, but present no peculiar agreements with those of the great Yorkshire coal tracts, either in thickness, or succession, or quality of coal, or nature of accompanying rocks. Some of the coal of Ingleton is of the nature of cannel coal.

The following are the specific gravities of several sorts of coal found in the district of Bolland, Kirby Lonsdale, and South Lancashire, from my own experiments.

Coal of the millstone grit and limestone series.

Casterton fell—slaty, does not soil, shining, a little pyritous, smokes, but gives little flame	1·623
Bentham, hard slaty, white ash	1·356
Ditto	1·295
Hutton roof—micaceous, slaty, sandy loose, without distinct grain, (or vertical cleavage) absorbs .027 of its weight of water	1·557
Borwick—clean, shining, stripy coal, with curved faces	1·505 & 1·463

Coal of the Ingleton field.

Ingleton—clean, shining, faces curved, crackles in water (absorbs ·015 its weight of water)	1·231 & 1·235
Ditto angles of cleavage 64° to 70°	1·195
Ditto angle 54°	1·310
Burton	1·242

Coal of South Lancashire.

Cromwick near Bolton	1·331
Lancashire cannel, crackles and bursts in warm water	1·199

Coal of the Durham field.

Rainton—the Hutton seam clean with sparry joints	1·204
Monkwearmouth—the upper seam (Bensham seam) from a depth of 264 fathoms	1·278

The heavy coals are in general more earthy than the others; sometimes more pyritous. This might be a test of some practical value. The Lancashire cannel is the lightest coal that I have tried, the coal of Casterton and Hutton Roof the heaviest.

NEW RED SANDSTONE SYSTEM.

In the vale of Eden and in Lonsdale this system consists of three divisions. The lower part is a calcareous breccia or conglomerate, commonly called brockram; the fragments are limestone and chert, often containing organic remains, of all sizes from seven or eight inches diameter to small pieces, and of every degree of attrition, but mostly in the state of small angular chips; the base is red sandstone; the beds very irregular. It is confined to the vicinity of Brough, Kirby Stephen, and Ingleton, and corresponds in age to the magnesian conglomerate of the central districts of England. The other parts are red sandstone and red marl, differing in no respect from those of other districts. No fossils have yet been detected in these beds: but the discovery of axinus, avicula, &c., in the red marl near Manchester, encourages an expectation that such may be found by diligent examination further to the north.

CHAPTER V.

Physical Geography of the District.

GENERAL DESCRIPTION.

The topographical divisions of the surface of Yorkshire correspond in a striking degree to the limits of the variations of its interior strata, and it appears possible not only to characterize these divisions on a great scale by general geological distinctions, but even to shew that the minute peculiarities of each, the form of the hills, the course and features of the valleys, the aspect of the vegetation, and the varying effects of the scenery, are all dependent on fundamental differences of interior structure. The vale of York separates by a wide interval the two hilly portions of the county; but even were this removed, the chalk and oolite hills of the east would still be distinguished by the topographer, the artist, and the agriculturist, no less than by the geologist and the miner, from the coal and limestone tracts on the west.— And as, on the eastern side of the county, even the least attentive observer acknowledges the real distinction of physical aspect and geological structure between the chalk wolds and the oolitic moors, so the western hilly tracts naturally resolve themselves into two great groups characterized by the presence of the remarkable formations of coal and mountain limestone.

The great variety of geological interest connected with the limestone tract of Yorkshire requires that this Volume should be principally devoted to it; but a right understanding of its geology and topography can hardly be acquired without a short survey of its connexion with the coal tract on the south and the great vale of York on the east.

An observer stationed on the swelling margin of the eastern wolds, at an extreme height of eight hundred and five feet, or on the steep escarpment of the oolitic moors, which rise to one thousand four hundred and eighty-five feet, may look to the westward over a uniformly low plain or vale, which from the Tees ranges southward across the Ouse, Wharfe, and Dun, and is, with some variation of character, prolonged parallel to the Trent as far as Nottingham.— Through all this extensive course, it is flanked on the east by lias clays and limestones, which are themselves overlooked by parallel walls of oolite and chalk, and on the west by a regular terrace of magnesian limestone. From one end to the other it is underlaid by red and coloured clays and sandstones, which, by some ancient devastations of water, have been deeply and irregularly excavated into subterranean valleys, and again overspread by vast heaps of transported materials. In particular places these materials lie in undulated ranges of hills, indicative of the direction of powerful currents, but in that portion of the great plain which belongs to Yorkshire the wide uniformity of the surface is seldom broken, except by insulated hillocks which rise barely to the height of one or two hundred feet above the sea.

The terrace of magnesian limestone above-mentioned rises, in almost all situations in Yorkshire, by an imperceptible gradation out of this great plain of new red sandstone, to a height of two hundred, three hundred, and four hundred and fifty feet, and ends towards the west in a well marked often very abrupt escarpment of one hundred or more feet descent. The strata lying beneath the limestone terrace on the west are unconformed to it both in dip and direction; consequently, in different situations, different strata come in contact with the lower plane of the limestone series. From the southern border of Yorkshire nearly to the river Wharfe, the magnesian limestone rests on coal measures; thence northward to the Tees on the subjacent strata of millstone grit and shales of the mountain limestone series; the general aspect of the western country varies accordingly.

The southernmost portion or proper coal tract is a vast slightly concave surface, rising near Sheffield to the south-west, near Huddersfield to the west, and near Leeds to the north, every where ending upon surfaces of millstone grit and other strata associated with it which rise still higher, and form the summit of drainage along the boundary of the county. The unequally resisting materials of this great area have been unequally acted on by atmospheric, fluviatile, and diluvial agencies, so as to present ranges of hills along sandstone, and lines of valleys where shale prevails: and thus the whole coal tract of Yorkshire is agreeably diversified with a succession of intricate though continuous undulations, seldom witnessed in other coal countries. Great facilities are thus afforded to the discovery and working of coal, ironstone, flagstone, fire-clay, and other products, and it is probable that in no district of Great Britain have these advantages been better understood or more vigorously prosecuted.—In consequence the succession of strata is perhaps better known than in any other coalfield of equal extent, and the continuity of particular seams of coal and layers of ironstone, for a length of thirty or forty miles, admits of satisfactory demonstration.

The millstone grit rocks which are the floor of this coalfield have their outcrop on the hills which overhang the southern bank of the Wharfe from Harewood to near Skipton; from this high point they return to border more closely the Aire nearly to Leeds, and rise again along the south side of that river by Bingley to Keighley, where they join themselves to the general summit of drainage which they follow into Derbyshire without once permitting the appearance of the subjacent limestone, though a considerable thickness of calciferous shales occurs below the grit in several valleys.

From the Wharfe northwards to the Tees the millstone grit series is largely developed, but no portion of the superior or true coal measures is seen in all this tract, though immediately on the north of the Tees, as on the south of the Wharfe, they appear in full force. Other thin seams of coal, however, of inferior quality, occur amongst

the alternating sandstones and shales of the millstone grit and limestone series, and thus justify the classification of all the groups in one carboniferous system, but they are but a subordinate feature in a region which derives its great lineaments from rocks which do not occur in the true coal tract.

It is the mountain or metalliferous limestone which gives to the north-western part of Yorkshire and to the district of Craven those marking and distinctive features, which powerfully interest the geologist and the topographer, and lend an indescribable charm to many sweet pastoral dales, which lie in the shadow of bold mountains, girt with green belts or steep precipices of limestone and crowned with ruinous summits of millstone grit. The aspect of the mountain limestone tract in Yorkshire is in some degree peculiar: for both to the north and south of the county the limestone series is considerably modified; and while in Durham and Northumberland the characters of this rock are less conspicuous, in Derbyshire they become more predominant. It is further to be remarked that even within the limited range of Yorkshire the composition of the limestone series varies so much, as to wholly alter the physical aspect of the country, and thus to give to the rocks near Ingleborough some of the massive features of the precipices of Derbyshire, and to the moorlands of Teesdale the desolate appearance of the valleys on the higher branches of the Tyne.

The limestone tract of Yorkshire may be considered as divided into two unequal parts, by a line drawn E. S. E. from Kirby Lonsdale to Skipton; the southern portion which is much the smallest forms a part of the country of Craven, and is geologically related to the mountain limestone of Derbyshire; the northern portion, which extends eastward along the Wharfe to Wetherby and goes northward to Teesdale is a part of one vast elevated region which ends abruptly on the southern side of the Tyne. The high western border of this region receives the appropriate name of Penine chain.

From the Penine chain to the parallel magnesian limestone ter-

race, and from Teesdale to the parallel line of Wharfedale and Craven, is a large rhomboidal area sloping with considerable regularity toward the east, nearly as the strata decline, though, in consequence of watery action, what was once a great uniform plateau is now dissected into a multitude of dales, ramifying among insulated mountains. The highest points in this area are those which are extended farthest to the west on the Yorkshire side of Teesdale; the millstone grit of Water crag, Wild Boar fell, and Shunnor fell, is higher than any points to the eastward; Wharnside is loftier than Ingleborough, Ingleborough than Penyghent, and Penyghent than Fountains fell.

DECLINATIONS OF STRATA.

The general slope of the whole Penine region north of the Craven fault from the axis of the Penine chain, indicated by the leading features of the country, is fully confirmed by the accurate measurement of the dip of the planes of stratification. Taking the well defined upper surface of the main limestone, which is the bounding plane of the Yoredale series, for our standard, we find that in Wharfedale, under Great Whernside, this is one thousand six hundred to one thousand seven hundred feet above the sea; in Low Birks one thousand seven hundred feet; in Fountains fell one thousand nine hundred feet; in Penyghent one thousand nine hundred feet; in Wharnside, south end, about one thousand nine hundred feet; in Ingleborough two thousand one hundred feet. This is the loftiest point of the mainlimestone south of Mickle fell. Parting again from Great Whernside, and proceeding north-west between Wharfedale and Yoredale, along the most connected mass of very high ground in Yorkshire, we find the main limestone ascend to one thousand eight hundred and fifty feet under Buckden pike; to one thousand nine hundred feet at Bishopdale head; and reach its maximum of elevation of one thousand nine hundred and twenty feet in Cam fell. *In Yoredale* the main limestone is found at East Witton four hundred feet above the sea. Hence passing westward and south of the

Yore we find it in Middleham moor eight hundred and fifty feet, in Pen hill twelve hundred feet, in Bear's Head nineteen hundred feet; on the north side of the Yore it is found at Leyburn seven hundred feet, above Bolton castle thirteen hundred feet, between Askrigg and Muker seventeen hundred feet, on the south side of Lovely Seat seventeen hundred feet, in Cotter fell (not the hill so named by Mr. Nixon) sixteen to seventeen hundred feet.

In Swaledale at Richmond the main limestone is three hundred feet above the sea, hence it rises westward south of the Swale to Downholme eight hundred feet, Sattron Hangers sixteen hundred feet, north side of Lovely Seat fifteen hundred and fifty feet; and north of the Swale, to Marsk, nine hundred and fifty feet, Fremington edge one thousand feet, Calvey sixteen hundred feet, Arkendale head thirteen hundred feet. At Swaledale head the main limestone is elevated seventeen hundred feet.

In Teesdale at Rokeby the main limestone is four hundred feet above the sea, hence it rises westward along the Greta to Bowes nine hundred and forty-two feet, and Stainmoor fourteen hundred feet; under grits and shales north-westward to Middleton one thousand feet, and Mickle fell two thousand five hundred and thirty-three feet.

Axes of declination.—Besides this *general slope* from the Penine fault, we find local slopes related to certain valleys and other marking lines of physical geography. There is a decided and constant slope from the edge of Wharfedale to Wensleydale, which is evident in all the ridges between the southern branches of Wensleydale. The main limestone at Coverdale head is elevated sixteen hundred feet above the sea, and it sinks north-east to East Witton twelve hundred feet in twelve miles: under Buckden pike it is eighteen hundred and fifty feet; at the head of Walden dale sixteen hundred feet, but sinks north-east to twelve hundred in Pen hill; at the head of Bishopdale it is nineteen hundred feet; hence the dip to Pen hill north-east is seven hundred feet in seven miles, but in the direction north-west, the rock ranges level, for it is equally high in Bear's head. This result of a maximum

dip to north-east from Wharfedale toward Wensleydale may be extended as far as Widdale fell. A northward slope may also be traced in Wharnside and from this mountain to Bar fell, and north-east to Cotter fell. Partial dislocations have little effect in this whole region, which is therefore proved to have a regular dip of one hundred feet per mile north-east, for the whole area between Wensleydale, Wharfedale, and the Penine fault.

North-easterly dips are often locally evident in the area between Kettlewell dale, Ribblesdale, and the Craven fault, they are very decided in all the region of Ingleborough (as Mr. Nixon has shewn very satisfactorily in Phil. Mag. and Ann. for 1828), and making every requisite allowance we find as a general result, that from the Craven fault for a considerable breadth to the N. N. E., there is a steep northerly slope, combined with the general eastward declination; this local slope being perhaps broken into two parts by a ridge on the north side of Wharfedale, and probably steepest near the Craven fault, and on the south side of Wensleydale.

We may now inquire how far this continues to the north, by taking as a standard the elevations of main limestone on the south side of Wensleydale. At East Witton this is four hundred, in Pen hill twelve hundred,—in Addleburgh (calculated) eighteen hundred in Bear's head nineteen hundred. From Bear's head passing due north to Lovely Seat we find the surface of main limestone fall two hundred feet in three miles: to the north side of Lovely Seat, a fall of three hundred feet, in five and a half miles; from this point to Keasdon mount, nearly level. In the north face of Water crag the limestone is four hundred feet lower, but this is less due to dip than to the effect of the east and west veins of Swaledale.

Again, from Pen hill northwards to Bolton fells, the main limestone is nearly level or even rising north, and this character obtains as far as Fremington edge; from Leyburn to Downholme also the limestone rises slightly; from Cotter fell to Swaledale head the beds form a shallow trough. The proper conclusion from all this is that the declination

of strata from the Wharfedale axis soon becomes insensible to the north of Wensleydale; yet to a certain extent the whole area between Wensleydale and Lunedale is depressed, the bounding ridges passing through Mickle fell and Cam fell.

Stainmoor.—An important transverse fold of the great Penine slope affects the whole country between the Greta and Lunedale, so as to cause a general depression of the surface, of not less than four hundred feet, and an almost complete concealment of the whole Yoredale group, beneath wide undulations and insulated hills of the millstone grit series. This very wide hollow of strata may be conceived to depend on one nearly east and west line through the head of Arkendale and another nearly parallel to it along Lunedale: the dip being from these lines toward Deep dale and Balderdale. The effects of this great hollow are traced to the east in the extended coal tracts of West pits; and to the west its southward boundary coincides with the origin of northward dips from the slates of Hougill and Langdale fells. The coal measures and mountain limestone series are all affected by it; but the red sandstone of the plain of Carlisle apparently not.

Aldstone moor,—North-easterly dips characterize this mining district and are sensible in those of Durham and Allendale, and Blanchland, till we reach Tynedale, where the influence of the great dyke reverses the phenomena, and the strata begin to rise toward the Lammermuir.

It is thus proved that the whole Penine region, from the Craven fault to the Tynedale fault, is elevated upon the axis of the Penine fault, with an universal dip to the east (as determined by the surface of the main limestone) of from sixty to one hundred feet per mile; this general slope is combined with great transverse undulations, one of them extending far to the east and crossing the Penine fault to the west. It is in consequence of these undulations that the Penine chain, though more uniform in its aspect than most other considerable ranges of high ground, exhibits some local features worthy of notice.

Proceeding from the Tynedale fault southwards, the strata, rising south continually, reach their maximum of elevation in the region of Cross fell, Scordale head, and Mickle fell. In Cross fell (two thousand nine hundred and one feet high) the main limestone is about two thousand four hundred feet above the sea; in Dun fell, Scordale head, and Mickle fell it is from two thousand four hundred to two thousand five hundred and fifty feet, the greatest elevation which it reaches in the British Islands. Two things here deserve attention: it is west of and under this lofty region, that the grauwacke pikes of Knock, Dufton, and Murton, have been uplifted; and it is in the same country that the great Whin sill terminates towards the south. The inference in favour of extraordinary local energy of heat is obvious.

From the height of two thousand five hundred feet in Mickle fell, the main limestone drops rapidly, partly by south-east dip and partly by the great Lunedale fault, to one thousand two hundred and one thousand feet, and maintains this depressed level from Lunedale across Stainmoor forest, beyond which it rises again to one thousand seven hundred feet in Nine Standards and Fell end.

Hence along the margins of Mallerstang dale the main limestone declines for some distance to the south, being at the summit of drainage between the rivers Eden and Yore about one thousand four hundred feet high. This is also its height in Bar fell, but from this point it rises rapidly to one thousand nine hundred feet in Wharnside and Ingleborough, and then suddenly drops at least three thousand feet under the Ingleton coalfield. As the Cross fell elevation besides its general relation to the Penine fault was opposite to and based on a peculiar ridge of grauwacke, so the Wharfedale ridge besides its relation to the Craven fault corresponds to the detached slate group of Hougill fells: and the Arkendale ridge is coincident with the north front of Langdale fell. Between the Mickle fell and Arkendale ridge is the great Stainmoor and Lunedale trough ranging E. by N.:—between the Arkendale and Wharfedale ridges

is the less obvious trough of Swaledale; from the Wharfedale ridge to the Craven fault is nearly a regular plane, declining to the east as all the hollows and ridges do.

These conclusions drawn from the levelling of the surface of the main lime, may be tested by a similar research as to the surface of the lower limestones. This limestone about one thousand one hundred feet high in Kingsdale sinks northward two hundred to Dentdale, and, this dip continuing, it is not seen in the greater part of Garsdale, nor in Mallerstang. On the south front of Ingleborough it is about one thousand three hundred feet, and about Ribble head one thousand feet high. Between Penyghent and Fountains fell the lower limestone is about thirteen hundred feet high; hence the northward dip causes it to sink to eight hundred and fifty feet on the south side of Hawes and to eight hundred on the north side. It is scarcely seen in Swaledale, which is not quite so deep as Wensleydale.

Under Great Whernside its elevation is about fourteen hundred feet, and due north of this in Wensleydale it is only about seven hundred feet. In the northern districts also we have proofs derived from the lower limestones, as well as from the upper, that the Mickle fell region is on a subterranean ridge, and Stainmoor and Swaledale in a subterranean hollow. Under Scordale head and Dun fell the Tyne bottom limestone is about one thousand eight hundred feet above the sea, but above Brough not half this height: and in the interior of the county it is nowhere seen between Lunedale and Swaledale.

In the region south of the Craven fault, the surfaces of stratification undulate in strict dependence upon the numerous anticlinal and synclinal axes of subterranean movement. The elevations caused by these ridges is always far less than those depending on the great Penine disruptions; the declinations of strata are however not less abrupt.

ELEVATION OF GROUND.

It will be convenient to class the observations according to four principal regions;

First, the grauwacke region west of the Penine fault; *secondly*, the grit, shale, and limestone country south of the Craven fault from Kirby Lonsdale to Wharfedale; *thirdly*, the gritstone border of the Yorkshire coalfield extending northward to the anticlinal axis of Greenhow; *fourthly*, the great Penine region from Teesdale to the axis of Greenhow and the Craven fault, and from the Penine fault to the magnesian limestone.

The elevations as given in the Trigonometrical Survey of Great Britain are marked (O. S.), those given by Mr. Nixon (N.) the others depend on my own measures.

West of the Penine fault.

The grauwacke hills under the northern parts of the Penine escarpment rise from 1200 to 1800 feet above the sea, and are consequently higher than a large portion of the limestone beds in the Penine escarpment.

Hougill and Langdale fells, part of the great range of the Westmoreland slate mountains, rise to their greatest elevation in the hill called the Calf, which according to the Ordnance Survey is 2188 feet, but by Mr. Nixon is stated to be 2220. Between Sedbergh and Kirby Lonsdale the grauwacke forms a line of round-topped peaks, of which the highest called Birkin is 2000 feet according to Nixon. In its eastward course from Kirby Lonsdale to Ribblesdale the grauwacke forms the base of a remarkable hollow between limestone hills, and nowhere attains a greater elevation than in the little valley of Wharfe and on the south front of Moughton fell, where, according to Mr. Nixon, it is 1166 feet high.

South of the Craven fault.

The insulated mass of Pendle hill, is 1803 (O. S.) or 1829 (N.) feet high.

In the Bolland grit and shale districts Bleasdale forest rises to 1709 feet (O. S.) and many other points are probably from 1200 to 1800 feet high.

In the lower parts of Craven, lying between the Ribble on the west and the group of Pendle hill and the border of the Yorkshire coalfield on the east, the elevations are of small importance. The aspect of the country is however singularly undulated by a multitude of small round hills or oval ridges.

Between the parallel Craven faults, the district from Ingleton to Settle seldom exceeds 1000 feet in height: Feizer hill (limestone) is 1109 feet (N.) East of the Ribble, Malham tarn is 1249 (N.) and Kirby fell (limestone) is about 1800 feet (N.) South of the Craven faults is a narrow band of elevated gritstone country, which, from Giggleswick and Settle eastward to the Wharfe, presents a singular rivalry to the limestone band *between the faults*. Thus at Giggleswick scar the grit is opposed to the limestone, (both about 1000 feet high), so Ryeloaf 1795 (N.) opposes the limestone of Kirby moor .1800, and the grit of Brown hill 1258 (N.) meets the limestone of Boardley, 1352 (N.)

Border of the Yorkshire Coalfield.

This border is formed of the millstone grit series resting on the Craven shales, which, only in Lothersdale and the Skipton ridge, are excavated so as to shew the subjacent great limestone. Continuous with the analogous mountains of Derbyshire the gritstone border of south-western Yorkshire ranges N. N. W. and dips to the east, from near Hathersage to Boulsworth hill. It then begins to veer round to the north, turns parallel to the Skipton anticlinal, and follows the south bank of the Wharfe, but spreads outliers, to the north of that river, parallel to the Greenhow limestone ridge.

The loftiest point of Derbyshire, Kinder Scout, 2150 feet (O. S.) is not equalled by any of the Yorkshire mountains on this range. Boulsworth is 1689 (O. S.) and Sutton crags 1161 (N.) Between Airedale and Wharfedale the long continuous ridge slopes in general eastward; at Shode bank E. S. E. of Skipton 1223 feet (N.) Draughton hill nearer Wharfedale 1074 (N.) Rombald's moor 1308 (O. S.) or 1318 (N.) Otley Chevin 921 (N.) Otley Chevin inn 799. Rawdon Billing 769 (N.)

The northern outliers of this great region form two very natural districts, one lying between the Craven fault and Greenhow ridge on the north and the Skipton and Blubberhouse line of elevation on the south, the other occupying all the space between this latter line and the Wharfe.

In the northern tract the upper millstone grit exists in great force in all the hills from Flasby fell, by Rylstone and Burnsall fells, to Symon seat, Poxstones moor, Guisecliffe, and Brimham rocks, whence it may be traced eastward toward Fountains abbey. This ridge is highest at its northern edge and on the sides of Wharfedale. Flasby fell is 1170 feet (N.) Burnsall fell 1505 (N.) Barden fells 1663 (N.) all these are west of the Wharfe. In the other direction, Carncliffe 1471 (N.) Lord's seat 1585 (N.) Symon's seat 1593 (N.) Poxstones moor 1513 (N.) High crag 1325. Padside on chert beds below Brimham grit 923. Guisecliffe 1000. Brimham 1000.

In the southern tract we may distinguish two parts; that surrounding Great and Little Almscliff, and that west of the Washburn and north of the Wharfe. Both these are gritstone districts, without any other trace of limestone than some debased cherty beds with fossils about Harrogate.

1.—Great Almias cliff 716 feet (N.) Little Almias cliff 837 (N.) Jacks hill 951 (N.) are rocks of the upper millstone grit. Harley hill near Harrogate, 596 (N.) Hill above Kirby Overblow 410. Stainburn chapel ground 461 (N.) Brisco Rigg 747. Brackenthwaite farm 537.

2.—Beamsley rock, (upper millstone grit) 1310 feet (N.). Gaisegill on the same ridge 1332 (N.) Summit between Kexgill and Wharfedale on beds a little above middle grit 940. Point on the Otley road above Farnley crag 830.

Penine Region.

Upon the wide, undulated, and partially dismembered surface of the Yoredale series from Cross fell to the line through Jervaux, Kettle-

well, Ryeloaf, and Lancaster, rests the millstone grit series of rocks; and south and east of that line the same series rests on the great united mass of lower limestone. Every where this upper series of rocks lies in insulated or highly ramified masses, according to the drainage and other circumstances. On some hills only the lower members appear, on others nearly the whole series, and these differences are reducible to a general rule which may be thus expressed. In the much elevated districts the lower portions only of the millstone grit series remain on the limestones, but in the lower regions the whole or nearly the whole series exists. This applies as well to the local inequalities of level occasioned by faults like Burtreeford dyke, as to the greater undulations previously described.

In the region of Mickle fell and Cross fell, where the main limestone is 2530 feet high, the highest summit, Cross fell, is only 370 feet above that level; in the depression of Swaledale and Arkendale, where the main limestone is about 1300 feet above the sea, 850 feet of upper beds appear in Water crag; in Ingleborough where the main limestone is 2130 feet high, only 260 feet of gritstones lie upon it, but in Wharnside the limestone 1800 to 1900 feet high has 500 feet of covering.

From these and many other data it seems probable that the superficial waste of the whole region has been in a remarkable degree proportioned to its elevation. The following measurements of hills partly derived from the Ordnance Survey, and Mr. Nixon's Trigonometrical and Barometrical Observations combined with my own researches, are classed according to the districts intervening between the dales; the rock of the summit is often named: and its elevation above the main or lower limestone generally specified.

Between Teesdale and Lunedale, on the elevated side of the Lunedale fault, the strata of the mountain limestone attain their greatest elevation in the British Isles. This district has an irregular surface, much affected by dislocations; its culminating points are Mickle fell, and the hills on the western or Penine border. The vale of Eden on

the west is about 300 feet above the sea: Dufton is 585 feet high, the Penine escarpments are from 1500 to 2300 feet.

Mickle fell; the highest summit in Yorkshire, is capped in the eastern part with a small patch of grits, and on the western part a more considerable mass appears and rises to nearly 2600 feet above the sea. The height of the main limestone is not less than 2533½ feet. This may be taken as the maximum height of that rock in the whole region round the head waters of the Tees: in Dun fell it is 2526 feet, in Scordale head 2437 feet, head of Knockoregill 2200 feet, surface of the Whin sill at Knockoregill above 1800 feet, at the Bridge of Caldron snout 1489 feet, at the High force 1000 feet.

Between Lunedale and the vale of Greta is the great depression south of the Lunedale fault—its highest points are on the Penine chain under 2000 feet; Brough at the foot of Stainmoor is 587 feet; the escarpment from 900 to 1300 feet.

Goldsborough, crowned with the middle or Arkendale millstone grit, is 1360 feet above the sea; at Howbeck head, near it, limestone and coal occur 1212 feet in height. Lartington moors, on the shale series below the grit of Goldsborough, Cragg, and Cat castle, are about 1165 feet, and Lartington hall on the same strata 735 feet.

Stainmoor, at the summit of the great road (in the limestone and coal series above main limestone) is 1448 feet high; the hills crowned by the middle grit towards the north rise 300 or 400 feet higher. South of it is the wide hollow of Greta dale, and eastward the road descends by Stainmoor inn 1262 feet, to Bowes (on main limestone) 942 feet, and Boldron hill (on the same rock) 883 feet, to Greta bridge (on strata below it) 441 feet. About 60 feet lower is the junction of the Tees and Greta.

Between the Greta and Arkendale, the southward rise of the strata is not insensible, and the hills resume somewhat of their importance.

The passes at Arkendale head and Cross of Greta are probably 1500 feet high.

Between Arkendale and Swaledale is a high digitated region with a great mass of millstone grit rocks over the main limestone.

Water crag, 2186 feet according to the Ordnance Survey, 2191 feet according to Nixon, has the main limestone 1357 feet high on the east side, 1273 feet on the south-west. Hall moor or Rogan's seat, at least as high as Water crag, is composed of the same strata. Its height by Nixon is 2207 feet. South-east of these points the country declines to Moulds, and Healaugh crags, both capped by middle grit, and Calvey, a mass of main limestone raised to 1600 feet (N.) From the east side of Arkendale to the vale of the Tees is an undulated region of 1000, 1200, and 1500 feet in Fremington edge, and Cross of Greet; to 1000 feet in the hills about Marsk; 850 feet in Richmond race ground; Richmond castle 450 feet; west of Water crag and Rogan's Seat, the same strata appear in Nine Standards, 2136 Ordnance Survey, (2153, Nixon). Kearsden mount, a fine insulated mass of limestone capped on the north end by gritstone, is 1643 feet high (Nixon).

Between Swaledale and Wensleydale, is a continuous range of high ground, terminating abruptly on the west in bold escarpments against Mallerstang, all about 2300 feet high—or 1000 to 1500 feet above that remarkable valley. The greatest masses of gritstone lie toward the extreme west, and toward the east—leaving in the middle part the main limestone at or near the summits.

Fell end and Hugh seat 2330 feet (N.), Lady's pillar 2261 (N.), exactly on the edge of this escarpment, have about 800 feet of grits, plates, and coal above the main limestone. Shunnor fell, more to the east, and of very similar composition, is 2329 feet (Ordnance Survey) (or 2351 Nixon); still farther east is the conspicuous hill called Lovely seat 2216 feet (Nixon), in which the main limestone is from 1554 to 1682 feet high. Eastward from Lovely seat the hills continually grow much

lower. Blakestone edge, 1928 (N.), Whitea fell or Pickington ridge 1855 (N.), Grinton Grits 1678 (N.), Robin Cross Hill 1407 (N.) All these are above the main limestone. In Sattron Hangers that rock is 1776 feet high.

The passes in this long mountain ridge, which I have measured, are the following. West of Lovely seat, the road from Muker to Hawes, (above the lower millstone grit), about 1760 feet; between Askrigg and Muker 1694 feet (on main lime), between Bolton and Reeth on beds below the middle millstone grit about 1500 feet, between Leyburn and Reeth on similar beds about 1000 feet. The main limestone at Leyburn inn is 700 feet above the sea.

Between Wensleydale, Wharfedale, Coverdale, and Widdale, is a large tract of elevated ground, rising uniformly toward the south-west; parallel to the plane of the main limestone. Waldendale, Bishopdale, and the branching valleys of Simmerdale, divide this region into four principal groups and ridges, viz. the group of Snays fell, Cam, Dod, and Bear's head:—the ridge of Stake and Addleburgh;—Wasset fell;—and the range from Buckden pike to Pen hill;—a fifth narrow region is on the escarpment edge over Wharfedale, between Cam fell and the head of Bishopdale. The height of the ground is proportioned to the position of the point on the inclined plane of the strata, and the mass of grits, &c. above the limestone.

Cam group—consisting of ramified Yoredale limestone, covered by three insulated patches of grit rocks. *The main limestone* in Cam fell 1924 feet (N.) In Bear's head 1946. The *grit summits* of Dod fell 2184 (N.) Bear's head 2019. Ten end 1919.

Stake fell—(a little grit over the main lime) 1843 feet (N.) Addleburgh capped by underset limestone? 1565 (N.) Summit of road from Bainbridge to Buckden 1901.

Wasset fell—(grit on main limestone) 1876 feet (N.)

Buckden pike—(grits over the middle grit) 2304 feet (N.) Main limestone on the west 1850 feet. Pen hill—(middle grit on the top) 1764 feet, (1675 feet N.) Main limestone on the north 1200 feet.

Edge of Wharfedale.—Yokenthwaite moor, grit over limestone 2111 feet (N.) Deepdale moor 1991 feet (N.)

The south-eastern side of Coverdale is guarded by a long ridge almost exactly corresponding to that on the north-west. Great Whernside 2310 feet (N.) (2263 feet Ordnance Survey) answers to Buckden pike, and Rover crag, over Scrafton 1552 feet (N.) to Pen hill; the intermediate heights are Little Whernside 1985 feet (N.) Great Haugh 1786 (N.) North Haugh 1677 feet.

From this ridge several groups of gritstone hills pass off to the east and south-east. The group of Witton fell, north of Colsterdale, is an undulated moorland surface sinking fast to the east from Rover crag and Fell crag to Fearby and Masham, a descent of 1200 feet in eight miles. On the road from East Witton to Colsterdale, the central ridge is 1109 feet above the sea. The highest rock is middle grit, of Agra crags, as far as Healey where upper strata come on. Between Colsterdale and Nidderdale, a wide undulated surface of gritstones, plates, &c. stretches from Great Haugh and North Haugh, having on the edge of Nidderdale, the highest part of the region, beds above the middle grit. Here it rises above Gowden Pot, to about 1450 feet, sends out a ridge north-eastward by the rocky border of Swinton dale to Masham and Hack fall; and another by Writhen stone, Hambleton hill, and Dallow crags to Brimham rocks, where the upper grit is 1000 feet above the sea.

Between Hack fall and Brimham the drainage of the Laver occupies a large nearly circular depressed surface. From Brimham eastward and south-eastward the undulated surface slopes irregularly toward the magnesian limestone.

Between Nidderdale, Wharfedale, and the ridge of Greenhow hill is a large dull tract of moorlands, composed of gritstones of the lower and middle groups, and the argillaceous layers above and below them. The strata in these wide moors rise north-west to connect with Great Whernside, and turn up on the south toward the anticlinal ridges of Greenhow hill. Meugher fell in the midst of this tract is 1897 feet (N.) The limestone of Greenhow hill is 1323 feet high. The inn 1181 feet. Devil's bridge 712 feet.

Between the Craven fault and Upper Wharfedale is a large somewhat oval space of lower limestone, much elevated; and only partially covered with limestones and shales of the Yoredale series. This covering between Langsterdale and Littondale inclndes main limestone and some of the superior beds, rising in Birks to 1949 feet (N.), in Litton hill to 1989 feet (N.), and Raisegill hag to 1987 feet (N.) In the upper end of Langsterdale Cam rakes below main lime is 1664 feet (N.), and Cash Knot near Penyghent, is 1933 feet (N.) Hardflask on limestone probably of the Yoredale series, the shales having become nearly extinct, 1745 feet (N.) Coska moor on beds above the main limestone 2050 feet (N.) Fountains fell on coal strata above the Ingleborough grit 2190 feet (N.), and Penyghent onthe same beds 2284 (N.)

Ingleborough, an outlier of the last tract based on the lower limestone surface and capped with lower millstone grit, is 2384 feet (N.), or 2361 (O. S.): the main limestone 2135 feet (in Simon fell); the Dent or Hardrow limestone at its highest point S. by W. of the summit 1467 feet. The grauwacke three miles above Ingleton 750 feet. Thornton bridge, spring of the arch, 2001.7 feet below the summit. (All these measures from Mr. Nixon.)

The Wharnside group, truncated on the west by the Penine fault, and on the south by the Craven fault, is double; having Wharnside 2414 feet (N.) or 2384 feet (O. S.), and Great Colm or County stone 2253 feet (N.) above the sea. The main limestone is 1800 feet to 1900

feet in Wharnside: the lower scar limestone spread widely, for its base, at a height of about 1000 feet on the south side and 900 feet on the north. Wharnside is the loftiest point in Yorkshire south of Mickle fell.

Rysell and Widdale fell, separate Dentdale from Garsdale; the latter reaches the great north-east valley from Ingleton to Hawes, and the former is truncated by the Penine fault. Rysell, capped by strata over the main limestone, is 1823 feet (N.), and the south-western end of Widdale fell (Woefell on the maps, Noutberry hill, Nixon), is 2205 feet high (N.); being capped by grits and coal shales above main limestone.

Bar fell (or Bow fell,) Swarth fell, and Wild Boar fell, unite into a remarkable group between the Penine fault and the valley of Helbeck and Mallerstang. Each of these summits has a thick load of gritstones (lower and middle grits) and coal shales above the main limestone; Bar fell is 2226 feet: Swarth fell 2237 feet: Wild Boar fell 2327 feet: main limestone about 1400 feet, in all these mountains.

DRAINAGE.

The system of drainage of any district presents problems of great complexity and varied interest, but the following are the most important conditions for the geologist to determine with respect to each valley.

First. Its direction and the relation of this to the strike, dip, and dislocations of the strata, and the nature of the rocks.

Second. The configuration of the valley, as to dimensions and slope of bed, in relation to the same circumstances, and the volume of water which continually or occasionally flows along it.

These things known, the great geological problem of the origin of valleys become definite in the particular instances, and can be solved

both as to dynamical agency and geological period, provided the level of land and sea is supposed to be the same now that it was before the valleys were made, or else to have varied according to a certain law. By these principles we shall be guided in the following inquiry.

The Penine chain is a summit of drainage, and the course of its longest streams is eastward, as exemplified in the Wear, Lune, Greta, Swale, and Upper Yore. There is, however, another principal direction observable in the Tees, Arkle, Lower Yore, Nid, and Washburn, and parts of the Upper Wharfe. We shall see hereafter that the direction of the streams, though primarily dependent on the dip of the strata, is subject to the controul of other circumstances. The Tees, the Swale, the Yore, the Nid, the Wharfe, and the Aire, which have their sources in the Penine chain, take separate courses through the magnesian limestone, but unite into one stream before reaching the Humber. Several streams of shorter course also break through that limestone, near Catterick, at Crakehall, and near Ripon.

In general the dales which ramify amongst the mountains of the Penine region commence at the summit of drainage, in hollows which are some hundreds of feet below the summits of the hills. It is to be observed that we are here speaking not of the actual water channels, which often are traceable nearly to the very highest ridges, but of the valleys which yield them a passage to the sea. This important distinction ought never to be neglected in works on Physical Geography. It frequently happens that the dale-heads of opposite drainages meet in a hollow boggy surface, which receives the rills as they gush from the mountain slopes, and yields at length two considerable bodies of water running in different directions. Thus Tynedale and Teesdale, Yoredale and Edendale, coalesce at their upper extremities.

It is also generally observable that the dales as they pass from the higher ground grow deeper continually for a certain distance, and expose along their sides lower and still lower strata; afterward this slope of the valley diminishes, and the stream passes successively over

higher and still higher strata, till it crosses the magnesian limestone. In the language of Mr. Smith, the streams in the Yorkshire dales first *overcut* and afterwards *undercut* the strata. Hence it happens that on the Tees, Swale, Yore, and Wharfe, especially, the lowest beds of the limestone series are exposed about the middle of the length of the dale, and in each valley waterfalls occur in the upper part, and rapids in the lower part, on the same limestone beds.

The lowest places on the summit ridge or Penine chain correspond generally to the terminations of the longest dales—as the head of Maize beck and the Tees in Teesdale, Stainmoor along the course of the Greta, Helgill at the head of Yoredale, and a pass at the head of Swaledale above Kirby Stephen.

Teesdale.—The Tees rises on the east front of Cross fell, which is 2901 feet high, (O. S.) flows eastward four miles through the Yoredale limestones to the Tyne bottom limestone, and receives on its right bank a stream called Trout beck, which flows north-eastward from a hollow in the Penine chain on the main limestone 2400 feet above the sea. The united stream flows south-east, first in Tyne bottom limestone, and afterwards in Whin sill, to the Weel, 1489 feet above the sea, then falls over the basaltic rocks of Caldron snout, about 200 feet, and receives Maize beck. The general course of Maize beck is E. N. E. One of its branches originates in a hollow of the Penine chain west of Scordale head, (called High-cup-nick), on Tyne bottom limestone 1850 feet above the sea. Another branch begins opposite Hilton beck, united to the preceding it flows in basalt to Caldron snout. From Caldron snout the Tees still runs E. N. E. till it receives the long stream of Harewood beck flowing south-east, which direction it takes and continues in basalt to below the Miner's bridge, thence south-eastward in Yoredale limestone, grits, and plates, to near Egglestone, having received on the right the Lune flowing E. by N., thence south-east to Egglestone abbey in plates and grits above main limestone, receiving on the right the waters of Balderdale and Deepdale, E. by N. Two miles below it receives the Greta.

The Lune rises in Mickle fell and Little fell, and flows eastward nearly parallel to and on the south side of a great dislocation as far as Grassholm bridge; it then turns north-east, passing deeply into the Yoredale limestones.

The Greta rises in a wide hollow of the Penine chain 1400 feet above he sea; flows eastward in strata above the main lime, enters that rock at Godsbridge, passes through the underset lime, flagstones, and third limestone, of Rutherford bridge, and again passes over these rocks and joins the Tees in the main limestone 380 feet above the sea. From this point the augmented river flows E. by N. for six miles *in the direction of the valley of the Greta*, till it receives Staindrop beck, whose direction to the south-east it then follows, and finally after many bends it turns north-east into the sea.

The dimensions of Teesdale vary according to the nature of the rocks through which it passes; and this independently of the magnitude of the stream now flowing. In the Yoredale rocks above Caldron snout it is a wide valley, contracted here and there by points of limestone; below this waterfall, though augmented by Maize beck and afterwards by Harewood beck, it is a narrower ruder dale with steeper borders more resembling a smoothed chasm than a gradually excavated valley: below the junction of Lunedale the stream-channel is contracted, but the dale spreads widely on either hand, in the argillaceous series above the main limestone; the slope of the valley, or rather of the river-channel, is most rapid in the upper parts. From High-cup-nick to below Caldron snout, six miles, is a fall of 550 feet; from this to the High force, five miles, 300 feet fall; hence to the junction of Lunesdale, six miles, 300 feet, and from this to the junction of the Greta eleven miles is a further descent of 300 feet.

To explain *the direction of* the Tees, the Lune, and the Greta, the following short statement will be sufficient. A dislocation ranges down Teesdale from a point below the High force to the junction of the Greta and beyond, causing a downthrow to the north-east: this is

the line of the dale. A dislocation of great amount, causing a downthrow to the south, follows the course of Lunedale; the Greta flows in a trough of the strata in all its upper parts; every considerable stream between the Lune and the Greta flows in the same E. by N. direction, or parallel to the dislocation and synclinal axis, and nearly in the line of the general dip.

Admitting that wide valleys were excavated by water streams proportioned to the magnitude of the effect, and that particular conditions of the stratification have directed the course of the stream, it seems at first extraordinary that there should be so many angular deviations in the course of one valley like Teesdale. Why should the Tees be deflected first into the path of the smaller river Greta, and afterwards into that of the still smaller stream from Staindrop? To answer this we must in imagination restore the original aspect of this region before the deep erosion of powerful waters. It is clear that whatever was their origin their effects were not necessarily limited to the present valleys: these are but the last effects; monuments may perhaps be found of many previous changes.

In this particular case I find some remarkable facts leading me to offer an opinion which many will think paradoxical, which I acknowledge to be bold, but believe to be at least not improbable. The accompanying chart will shew that in the very line of the Teesdale fault runs the little river of Gilling, dividing the more elevated limestone districts north of Richmond from the comparatively lower ranges under Gatherley moor. This dislocation, this valley, is merely in fact a prolongation of the great fault and valley of Teesdale; it opens at its upper end into the wide denudation round Greta bridge, and seems to have served in some ancient period, before the final adjustment of the present valleys to the actual levels of the surface, for the passage of water directed by the Teesdale fault. It appears to me that along this valley the waters of Teesdale flowed in earlier geological periods, and that the actual Tees now flows in the real

valley of the Greta after its junction with that river. It is remarkable that after receiving the Gilling water the Swale turns and takes the south-east direction.

Swaledale.—The head waters of Swaledale flow in various directions, but the main stream rising from several branches on the high margin of Mallerstang, amongst hills 2300 feet high, collects into an east and west valley coincident with the great dislocation which accompanies Fryerfold vein. From Stonesdale *a double* valley leads south to Muker; the mountain called Kearsden rises in the midst of this valley, a huge insulated monument of earlier nature. Here the main river receives on its right bank a little stream running east from Shunnor fell; and takes its direction. After a considerable course to the eastward it receives on the left bank the water of Arkendale, flowing to the south-east. Soon after the valley makes a short turn to the north, again runs eastward, receives the Gilling stream, and takes *its* direction to the south-east. It does not appear that the east and west course of Swaledale is the result of dislocations passing down that valley; it is indeed parallel to the east and west lead veins of Auld Gang, Arkendale, and Hurst; but the principal circumstance is the dip of the strata here generally east. Arkendale appears to be marked out by a dislocation parallel to the Teesdale fault, and in the same manner but in a less degree throwing down the strata to the north-east. The insulated mount of Kearsden, in the double valley above Muker, seems inexplicable unless on the supposition of the passage of a great body of water. On the west of that mountain the strata appear to be thrown down by a fault passing north and south along the valley and continued in Stonesdale. Admitting the passage of such great currents down Arkendale we naturally look for a continuation of their effects further to the south-east. In this direction from Marrick to Leyburn is the lowest tract of country between Swaledale and Wensleydale; and if we suppose the denudation of the limestone here to be the effect of the Arkendale current, we may see in the south-eastern bend of the Yore, at this point, an additional confirmation.

The bed of the valley slopes rapidly in the upper part above Muker, and then with much uniformity declines to the vale of York. Swaledale head (Hollow Mill Cross) 1700 feet, Muker 850 feet, Marsk bridge 545 feet, Richmond (rocks below the castle) 300 feet. The width of the valley varies chiefly in relation to the nature of the rocks. Its principal contractions are above Muker and above and below Richmond.

Wensleydale.—This magnificent valley opens at its head into the vale of Eden, Garsdale, Dentdale, and Ribblesdale, by passes of moderate elevation all under 1500 feet. At the point of union of Garsdale, Wensleydale, and Edendale, the eye looks northward along the deep hollow of Mallerstang, westward down Garsdale, and eastward through the whole length of Wensleydale. Where Dentdale, Ribblesdale, and Widdale meet, one deep valley stretches W. N. W., another flows north-east, a third to the south, a fourth, the Greta, runs south-west. Wensleydale is more intimately connected with Garsdale, in direction at least, than with any other of the valleys into which it opens; in a certain sense we may consider Garsdale and Wensleydale as one long east and west valley; but Garsdale is a narrow glen compared to the broad, fertile, and noble valley of the Yore. In its eastward course the Yore receives on its right bank Widdale beck, flowing north-east, Gale beck flowing N. by E., the water of Radleside dale, whose course is north-east, Bishopdale also north-east, Walden dale more nearly north, and Coverdale E. N. E. The streams which enter on the left bank are of less importance. In lower ground where it runs south-east, the Yore is augmented by the waters of Colsterdale flowing east.

The general tendency to north-easterly directions, in all the affuents on the south side of Wensleydale, is extremely remarkable, and certainly is dependent on the general dip of the strata, there almost invariably to the north-east. This same dip prevails in the upper end of Nidderdale and Colsterdale, where the direction of the drainage is nearly parallel. We have already shewn the apparent dependence of the south-eastward turn of the Yore upon the continuation of the current from Arkendale.

Perhaps it may be the case that a small fault ranges along the bed of Wensleydale; but this is principally to be accounted a valley of denudation, whose opposite sides fit remarkably. Heaps of detritus lie near Bainbridge, in the angle of Simmer water and the Yore, and considerable accumulations of the same kind occupy nearly a similar position in the angle between Bishopdale and the Yore.

The general slope of Wensleydale is moderate: in the upper parts it is not excessive. The summit of Helgill Lund (between Edendale and Yoredale) is in underset limestone 1210 feet above the sea: the summit toward Garsdale near 'Lund's Thorn' (the tree is no longer there), only 1050 feet; but the summit toward Dentdale and Ribblesdale (Newby head) about 1300 feet; Hawes inn (ground floor) is 820 feet, the valley there 770 feet; Bainbridge (the bridge top) 700 feet; Wensley bridge end 400 feet; Masham inn (ground floor) 339 feet; the valley there about 250 feet.

Of the lateral valleys it will be enough to mention the slopes of Bishopdale and Coverdale. The summit of the former against Wharfedale is a remarkable neck of land from which the descents are rapid each way, formed on the middle limestone of Addleburgh, elevated 1500 feet above the sea. At Langrigg 730 feet (the hills being 1800 feet high and precipitous); at Burton 570 feet. Coverdale ends in a similar neck of plain land against Kettlewell dale, formed on main limestone 1630 feet above the sea (960 feet above Kettlewell inn); above Dale Head the river is 1123 feet; Bridge on Gammersgill road 669 feet; Coverdale abbey 446 feet (river below the bridge).

Nidderdale.—The two head branches of the Nid, one (the Nid) descending straight from Great Whernside, the other (Steen beck) from Meugher fell, run with the dip of the strata north-east.—After this union, the Nid runs due south-east, till it has passed the Greenhow anticlinal ridge; then it turns due east to encounter the magnesian limestone at Knaresborough. The slope of the valley is rapid in the higher parts and moderate in the lower region. Angram Ford

about 850 feet; Gowden Pot hole 640 feet; at Lofthouse bridge the coral bed of limestone 540 feet; Pateley bridge 400 feet; Ripley 240 feet (estimated.)

Wharfedale.—The head waters of Wharfedale are collected from springs issuing below the Cam limestone and from lower rocks of the Yoredale series. The northernmost branch or true Wharfe flows eastward to Deepdale, then turns E. S. E. to Buckden, S. S. E. to Kettlewell, south to near Skythorn, south-east to Appletreewick, where it leaves the limestone series and enters the millstone grit. In this series it makes large bends, averaging a S. S. E. course to Addingham; it then turns nearly E. S. E. to Otley, and thence runs due east to the magnesian limestone. In its long course the Wharfe receives only two considerable feeders, the water of Littondale below Kilnsea and the river Washburn below Otley, both flowing south-east. The Wharfe is a uniformly rapid stream from its origin till it encounters magnesian limestone. Wharfe head is stated by Mr. Nixon to be 1264 feet above the sea, hence it falls to Deepdale bridge 364 feet, to Hubberholm bridge 133 feet, to Buckden bridge 35 feet, to Kettlewell bridge 63 feet, to Linton bridge 131 feet, to Bolton bridge about 180 feet, to Otley 130 feet, and to Harewood bridge 130 feet, being at this point 98 feet above the sea.

The breadth of Wharfedale is in general small; Langsterdale and Littondale are deep glens in limestone: below their junction Wharfedale widens and maintains a considerable expansion as far as Linton; it is contracted to a narrow glen between the grit rocks of Barden, escapes into a broader space below Bolton abbey, and becomes a wide vale as it proceeds eastward.

Ribblesdale.—This valley originates in the wide hollow between Blea moor and Cam fell in the strata of the Yoredale series. From Ribble head, which is some distance from the source of the longest streams, Ribblesdale ranges S. S. E. to Stainforth, and with great bends holds the same general course to West Halton; here it turns due

south-west, by Bolton, Clithero, and Ribchester, to the sea. Below Clithero it receives, nearly at the same point, two rivers on the opposite banks whose previous courses have a reciprocity of direction; the Hodder on the west and the Calder on the east flow for many miles parallel to each other, and to the principal stream, and both turn at right angles to their former courses to enter the Ribble. This singular analogy of direction receives an immediate explanation by comparing it with the anticlinal axes of Bolland and Craven, which also range north-east and south-west. A fault probably ranges across Ribblesdale and occasions the rectangled deviation of the Calder and Hodder, for in both instances the valleys in which they first ran are continued to the south-west beyond the point where they turn at right angles. Thus there are three parallel vales determined by the anticlinal axes of Bolland and Craven. Ribblesdale is nowhere greatly contracted except between the limestone hills about Settle. The slope of the valley is extremely rapid from Ribble head 1000 feet above the sea, to Horton bridge 750 feet, and Settle bridge 440 feet.

Drainage of Lonsdale.—Through the low country between the Bolland hills on the south, and Ingleborough and Graygarth on the north, flow the little rivers Greta and Wenning. Two small rivers, originating on opposite side of Wharnside, run in straight dales between lofty scars of limestone, cross the grauwacke ridge, and meet acutely at Ingleton to form the Greta; thence it proceeds due west to the Lune. The Wenning draws most of its waters from the gritstone hills on the south, it flows to the W. N. W.

Vale of the Lune or Loyne.—The river Lune collects much of its waters from small streams which run to the north with the slope of the grauwacke of Langdale fells: it is in fact a collecting drain for that region, and its westward course from Ravenstone dale to Tebay is determined by the subterranean movements which have uplifted the slates. At Tebay it receives some additions from the west and north-west, and turns due south through what may be looked upon as a chasm or natural fissure crossing the grauwacke

ridge; with some deviations it holds this course to the south, gradually bending toward the west as it approaches Lancaster. On the left bank it receives the united waters of Dentdale, Garsdale, and Rotherdale; the first excavated to an immense depth below the gritstone summits of Wharnside into the lower limestone, the second reaching only to the lower beds of the Yoredale series, the third principally fed by streams from the grauwacke district.

Vale of Eden.—The vale of the Eden is continuous with that of the Yore, and the head waters of these two rivers rise near to each other, and flow in parallel directions to the south-west, after which, without any remarkable intervening obstacle, the Eden turns to the north and the Yore to the south. The Eden flows for some miles in the deep glen of Mallerstang in rocks of the Yoredale series, then crosses dislocated strata of the Penine fault, passes through the breccia of Kirby Stephen, and turns to the north-west through the broad plain rather than vale of new red sandstone, between the Cross fell range and the limestone border of the Cumbrian slates. The lower part of its course lies in a great original hollow, the upper part is wholly a valley of denudation, nor am I aware of any peculiar dislocations likely to give origin to it. Considered in connexion with Garsdale and Wensleydale it seems to indicate the passage of great currents of water, raised by some convulsion of nature to more than their ordinary force and height, or else acting with greater advantage on land just rising from the sea or imperfectly consolidated.

Passage of Floods from the West.—It is impossible to close these brief notices of the drainage of the mountain limestone tract of Yorkshire without a few remarks on the presumed passage of floods of water in directions not related to the existing channels of drainage. No one accustomed to reason on the waste of the surface evidenced by the excavations of valleys, and to consider the present detached masses of strata as the remains of continuous deposits, the present hills and ridges as parts of a once unbroken surface, can be surprised at the notion that waters have formerly run and channels been scooped

out in directions quite different from those taken by existing streams: but it must always appear strange that waters should have flowed across what now are and must always have been natural valleys and ridges; that they should have crossed in their course many of the mountains of Cumberland and Westmoreland, left their spoils on the limestone hills of Orton, in the red sandstone vale of Eden, and on the summit of Stainmoor. Into the general history of the evidence by which it is supposed to be proved that currents of this violent description, flowing from the west and north-west, brought the granite of Shap fell, the sienite of Carrock, and other Cumbrian rocks, to the foot of the Penine escarpment, and lifted them with the brockram of Kirby Stephen over that mighty and ancient boundary wall which stood up in the primeval ocean, it would here be unnecessary to enter. But it appears worthy of remark that it is only *at Stainmoor*, at the *natural depression* on the great Penine escarpment, that the blocks from the western hills have crossed that immense barrier. I formerly thought that Stainmoor was the *lowest* pass of the Penine chain from Brampton to Ingleton, but accurate measures have shewn me that in fact the valley of the Eden offers a lower pass by 230 feet, for the summit between Mallerstang and Wensleydale is only 1210 feet above the sea and that of Stainmoor is 1440 feet. Yet it is only at this pass, from Brampton to Kirby Lonsdale, that any one stone from the slate districts has passed into the eastern valleys: and the reason I conceive to be this, viz. that Stainmoor opens to the west and north-west, from which, apparently, a tumultuous rush of waters suddenly came and quickly passed. Once lifted over the summit, the eastward descent to Teesdale, Gretadale, and the lower end of Swaledale, sufficiently accounts for the dispersion of the boulders of granite, &c. in these directions. Near the summit of Stainmoor 1400 feet, and on the insulated rock of Goldsborough 1360 feet, great blocks of Shap granite lie, as well as abundantly in the lower ground along the vale of the Tees, and on the moderately high ground about Scotton. Many of them are of surprising dimensions, and weigh from a ton to ten tons.

Airedale.—The principal stream of the Aire has a very singular origin. On the limestone hills above Malham is a large piece of water,

once larger than at present, fed from an immense area of dry rocks which absorb the rain and yield a part of their stores to this elevated lake.

Malham water is on the line of the North Craven fault, overlooked on the north by the limestone ranges of Hardflask and Fountains fell, while from below it rises to the south the depressed band of the same limestone. The natural exit of the water is in this direction, as a superficial channel distinctly shews; but instead of following this channel, to fall in a mighty cascade over the tremendous precipice of Malham Cove, the water sinks into the open-jointed limestone rock, and bursts forth in a full and perpetual stream at its foot. This is the Aire; it is speedily augmented by a stream from the cleft rocks of Gordale and other small branches, and flows south through an undulated country till its valley opens into the broader and more level regions of Craven. Here it receives on the right bank the water of Otterburn, running to the south-east; this course after some flexures the main river assumes. Below Gargrave it is augmented by a considerable stream from the north, and in its long course to the south-east other small rivers and brooks swell its waters to a considerable amount.

Airedale commences at Malham 680 feet above the sea, 570 feet below Malham water, which may be considered its source; between Malham and Skipton there is a descent of 300 feet, from Skipton to Leeds about as much. The valley is nowhere remarkably contracted in its course through the Craven shales and black limestones from Malham to Skipton, but at Kildwick, Keighley, Shipley, Calverley, and Bramley, the millstone grit rocks narrow its dimensions.

Besides the remarkable origin of the principal stream of water we must observe the exact coincidence of the line of Airedale, prolonged in the Otterburn branch, with the western portion of the Craven fault. On the north of this line from Kirby Lonsdale to Skipton is an elevated country, to the south of it the whole region is depressed; the north side of Airedale is higher than the south side, and it appears to me that the direction of this valley is really a consequence of the direction of the Craven fault.

SCENERY.

Though a description of the grand and beautiful combinations of natural objects, which have long rendered the mountains and dales of Yorkshire the resort of the lovers of picturesque scenery, would be foreign to the object of a Geological Treatise, some notice of the variation of scenery according to geological conditions may properly find a place. It cannot be necessary to offer proof that the principal characters of scenery have their foundation in geological circumstances. The effects depending on relative elevation may be traced to subterranean convulsions and local violence of water; to the same causes are due the endless varieties of combination which render a mountain group inexhaustible of interest; and the lesser features of the landscape, the peculiar outline of every mountain, the peculiar character of every waterfall, depend mainly on the composition and structure of the rocks and the order of their succession. Is the charm of fine scenery diminished because the secret agencies which have concurred in its production have become familiar to the reasoning geologist? surely he of all men should be the most affected by the charms of nature, who, in addition to the pleasure derived from contemplating the external aspect of creation, feels himself irresistibly led to connect the present configuration of the surface of the earth with great changes in its interior and exterior conditions, to unite the present with the past, and to view the manifold revolutions which have visited the earth as in no sense accidental, but parts of one general and continuous plan, singularly adopted to the moral and intellectual capacity of man.

The elevation of ground and ramifications of drainage having been already discussed, we may proceed to notice the combination of mountains, their individual features, and waterfalls.

Grauwacke region.—Every where in Yorkshire, and along its borders, the grauwacke hills present themselves with an individuality of form and an intricacy of association totally different from those of the lime-

stone region. The hills are usually somewhat conical, with steep straight slopes meeting in narrow, angular, variously directed valleys; individually some of the grauwacke hills, as Dufton pike, Murton pike, and the exterior hills of Hougill fells, are magnificent objects, and in some points of view their combinations are pleasing in Hougill fells; but they yield in grandeur to many of the limestone hills. The surface of the grauwacke mountains is usually green and smooth, the herbage coarse, in particular lines long ridges of rock rise above the general level in geometrical forms corresponding to the natural joints.

Along the line of the Craven fault the grauwacke shews these natural joints, and also the presumed planes of stratification, very completely, and their highly inclined planes of division, seen under the horizontal beds of limestone, produce a singular effect in the picture. The waterfalls are not numerous in this district. Cautley spout in Hougill fells is a lofty cascade, and on Barbon beck is a low force of great beauty. The most interesting, however, is that in Kingsdale near Ingleton, where the little stream falls over limestone and grauwacke: the latter rock occupies a very small space, looking like a small piece of the Westmoreland slate country unaccountably enclosed in a large area of Yorkshire limestones. *(See Diag. No. 13.)*

Old red sandstone.—This rock offers hardly the least comparison in respect of scenery with the lofty ranges and insulated hills of Monmouthshire and Glamorganshire; it more resembles the analogous deposits at the foot of the Lammermuir hills; it is seen only in low ground at the base of higher strata, and is quite unimportant to the artist.

Lower scar limestone.—Though this rock nowhere in Yorkshire rises to the highest ground, being every where overtopped by some neighbouring ridges or solitary hills of the Yoredale limestones and millstone grit, it is yet one of the most important and characteristic in the scenery of Bolland, Wharfedale, Upper Airedale, Ribblesdale, the whole Penine escarpment from Kirby Lonsdale to Cross fell, and on the side of the vale of Eden from Ravenstonedale to Shap.

In the latter district it forms a connected and independent ridge, about 1200 feet above the sea, with a bare dry surface, terminating to the south in a bold abrupt escarpment, traversed by several cross valleys; along the Penine chain, from Hartside to Brough, it forms the principal part of that immense escarpment which is one of the grandest features in English geography. From Kirby Stephen to near Kirby Lonsdale it is much less conspicuous, though very remarkable for its vertical position: from this point proceeding eastward the surface widens to form the ample base or general floor of the distant mountains of Graygarth, Wharnside, Ingleborough, Penyghent, Fountains fell, the Langsterdale fells, Buckden pike, and Great Whernside. On referring to the map, the great extent of this surface will be seen at a glance; a large portion of it is occupied by the gray rock destitute of herbage, except in particular hollows and along lines of fissures and joints. Where however the devastating effects of watery agency had been less complete and soil remains on the rock, the short green herbage characteristic of limestone agreeably diversifies the sterner aspect of these rocky plains.

The southern edge of this rocky and elevated limestone region is guarded by a continuous line of lofty precipices commonly called scars, from Graygarth to Wharfedale. About Ingleton, in Ribblesdale, on Malham moors, in Littondale, and Kettlewelldale, they have a peculiar grandeur, and form a magnificent base and fore ground for the lofty mountains which rise above them. In Greenhow hill, and Nursa Knot, at the eastern termination of this great limestone surface, the same general characters are well contrasted with the wide moorland district. *(See Diagram, No. 20.)*

In the interior dales, as in Nidderdale, Bishopdale, Wensleydale, Upper Swaledale, and Teesdale, its characters are less important in the scenery, though in the latter dale its upper portion is elevated upon the picturesque rocks of basalt.

In Wensleydale some waterfalls of considerable beauty are caused

by its upper beds, about Hawes, Bainbridge, and Askrigg. At the latter place is Bow force, one of the prettiest low falls in the dale. The waterfalls in Aysgarth are over this rock, and when water is abundant their effect is very fine.

In Bolland the surface of this limestone nowhere probably exceeds 1000 feet above the sea, it is not so bold in feature as the districts further to the north, but both here and about Clithero its aspect is similar.

One remarkable character of this limestone throughout its whole course in the North of England, and indeed through all parts of the kingdom where its mass is considerable and not much divided by interposed shales and grits, is the occurrence of subterranean caverns. These are far too numerous to be individually described, for they occur in nearly all parts where the limestone is elevated so as to permit water to pass downwards through the rock, or to justify a suspicion that in some former condition of the surface it may have passed: yet it must be remarked, that they are most frequent in those parts of Yorkshire where the limestone is thickest, and collected into one mass, and that they are frequently situated in the side of a valley. This is the case by Barbon beck near Dent, in Leck beck on the west front of Graygarth, Yordas cove in Kingsdale, Weathercote cove in Ingletondale, a cave in Claphamdale, Hurtlepots in Ribblesdale, a cave above Kettlewell, and Gowden Pot hole in Nidderdale. On the contrary in Greenhow hill, on the north front of Ingleborough, and in Bolland, this is not the case. From whatever cause the cave originated, in most instances each has been traversed by streams, or bathed by the dripping of water containing carbonic acid. Thus the cave has been in some instances enlarged and modified, and is still undergoing change, in others the original surfaces are partially or wholly encrusted with crystallized carbonate of lime left by percolating water, and sometimes hanging in long stalactites from the roof, or rising in wrinkled columns of stalagmite from the floor. The cavern in Greenhow hill, though little known and seldom visited, is one of the most remarkable

for its sparry accumulations which I ever saw. On its floor was a quantity of brownish mud, which might give rise to expectation of finding bones; I believe no sufficient trials were made. Gowden Pot hole is the entrance to a prodigious long flexuous subterranean narrow cavern, in places filled by the river Nidd, which here takes a subterranean course for one or two miles according to the quantity of water, and in almost all parts of the cave the sound of its waters may be heard as they rush along the secret channels of the limestone rocks.

Yoredale Rocks.—The varied features imparted to the scenery of the dales of Yorkshire, Durham, and Aldstone moor, are in general similar, and remarkably contrasted with the simpler aspect of the subjacent thicker limestone floors. Of the latter broad surfaces and mighty cliffs, with frequent and deep clefts, chasms, and caves, are the typical character throughout England and Wales: but the Yoredale series of shales, gritstones, and limestones, presents in every hill variations of feature corresponding to these different terms of the series, and the effect of the whole combined is quite peculiar. Yet as, north of the Craven fault, the lower limestones continually subdivide themselves, they assume in all the Penine chain from Brough northwards somewhat of the surface features of the Yoredale rocks, and in the wide moors of the west of Northumberland present hardly any points of constant difference. Where it exists complete, as in the head of Wensleydale, the Yoredale series admits of being exactly characterized in a drawing so that its parts may be again recognized in other situations. For example take the profile of a mountain whose top is capped with millstone grit, and base rests on the lower scar limestone; its whole slope being formed of Yoredale rocks 800 to 1000 feet thick and the series complete. The profile will present the following leading features. At the top of the series, under the rounded or angular craggy top of millstone grit, and perhaps a small edge of chert or little limestone, the main or twelve fathom limestone will project into a bold perpendicular scar; below it will be a little concave or flat slope terminated by a second and less con-

spicuous projection of the thinner underset limestone; a long slope succeeds, simple or slightly varied with rising undulations corresponding to the hard gritstones interstratified with shales; this ends above a single or double scar of the middle limestone, which is very conspicuous where thick, as in Addleburgh and Pen hill, but easily lost by the detritus of the superior rocks where it is thin, as above Hawes: below this is another slope to the Simonside limestone, which forms a smooth terrace; another steep slope to the Hardrow scar limestone, which runs for miles along both sides of Wensleydale in a remarkable terrace, occasionally woody, always very abrupt and rocky at the edge, and based on a steep slope of plates leading to the broad floors of the lower limestone series. It seems unnecessary to offer any other explanation of the prominent and retiring parts of this profile, than that afforded by the consideration of the relative resistance offered by the different rocks to the atmospheric agency and watery currents which have modified the surface of the country; the limestone is the most consolidated rock in the district and most capable of resisting the wasteful effects alluded to, hence its projecting scars: plate or shale is in this respect exactly the reverse, hence its soft uniform slopes: gritstone is of intermediate character and feature, but in the Yoredale series rocks of this nature are thin, much mixed with plate, and thus prevented, except in favourable circumstances, from appearing in a characteristic manner. Of the five limestone belts which encircle so many of the Yoredale mountains, the middle and lowest but one are the least constant: where these are indistinctly seen the interval between the upper or Cam belt of limestones and the lower or Hardrow scar limestone is enormous; but in proceeding northward to Aldstone moor this interval contracts and the scar lime of that valley, equivalent to the black limestone of Dent and Hardrow scar, is not so far removed from the upper belt. The profiles of the hills in Aldstone moor follow the same law: the limestones almost always project, the argillaceous beds form obscure slopes, certain thick gritstones (as the Nattriss gill hazle particularly) occasionally rough angular edges. (See in illustration of these remarks the Sections No. 1, 2, 3.)

Where the Yoredale series, by the extinction of its limestones and some of its gritstones, becomes almost wholly argillaceous, as in Ingleborough and Fountains fell, the profile changes. Then the main limestone and underset limestone conjoined or separately project into their usual mural precipices, and below them a nearly uniform slope of many hundred feet in descent conducts to the Dent or Hardrow limestone, which may or may not form a prominent belt according to circumstances. This depends very much on the thickness of the subjacent plates. (See Section No. 1, and Outline of Ingleborough No. 21.) In Bolland and the country south of the Craven fault the Yoredale series, being almost wholly shale with interlaminated limestones, presents only sloping surfaces below the gritstone summits, or smooth rounded hills in all the large region between Ribblesdale and the border of the Yorkshire coalfield, where no gritstone appears. These rounded surfaces of shale and limestone are also in many instances conformed to the interior dislocations of the strata. (See Outline No. 23 for the contrast of shale and gritstone hills in Craven.)

The facility of waste and tendency to form insular hills caused by the great abundance of shale in the Yoredale series is the cause of much of the grandeur and variety of the Yorkshire dales. To this cause we must ascribe the extensive denudations of the Yoredale series; the connexion of the dale heads of opposte drainages; and the enormous depth of the valleys. This facility of waste has cleared those prodigious broad limestone surfaces, on which at wide intervals stand the cones of Ingleborough, Wharnside, and Penyghent, deriving from their insulated position and happy combinations a grand and beautiful effect in the landscape, often denied to far higher but less favourably situated mountains.

The alternation of limestones, gritstones, and plates, which constitutes the essential character of the complete Yoredale series, is the cause of another beautiful feature in the scenery of the Yorkshire dales—the waterfalls.

These are found in all the dales, and most of the lateral valleys, where the Yoredale series occurs; but it is in Wensleydale, where that series is most complete, that the waterfalls are most frequent, varied, and interesting. It is difficult to resist the desire of describing some of these ornaments of Yorkshire scenery; for nothing can be conceived more delightful to a tired wanderer on the mountains, after a long day's hammering, drawing, and measuring, than to rest at the foot of the lofty cascade of Hardrow (96 feet), or listen to the everlasting murmur of the broken streams among the rocks and woods of Cotter force. (See Turner's beautiful drawings of these fine waterfalls.) The different picturesque falls round Hawes, in Moss dale, and above Gale, the two fine 'forces' on Millgill near Askrigg, Bow force, several falls in Bishop-dale, and round Simmer water, besides the well known cataracts of the Yore at Aysgarth, might afford more just subjects for description and painting than many more fashionable scenes. But I must be content to point out the cause or leading condition of all these falls. It is a constant law of such phenomena, that the upper part of the cliff of the waterfall is guarded by a durable ledge of limestone or gritstone, and its lower part formed of wasting argillaceous beds. It is not so much the absolute difficulty of *wearing* through limestone, or gritstone, as the relative facility of excavating shale, that makes the water 'force' as it is expressively termed in Yorkshire. The more rapid waste of the shales above and below soon reduces a channel of uniform descent to a series of terraces on limestone or hard gritstone, and steep slopes on plate; the further waste of these soft beds causes cascades at every ledge of rock; and in the continuation of the process the shales below a fall, incessantly crumbling away in the damp atmosphere, betray the foundation of the limestone, and breadth after breadth, block after block, yields, and falls, and thus the place of each waterfall is slowly changed, the edge of the rock recedes, and a long often tortuous avenue of lofty cliffs, which once formed the side screens of the waterfall, leads far into the mountains, before we reach the actual cataract (Millgill above Askrigg, Hardrow force, &c.) Amidst the great number of falls in the Yorkshire dales, very few (Millgill upper fall, and Aysgill)

are caused by gritstone layers; the same is the case in Aldstone moor; the finest in Wensleydale are in the Hardrow limestone, or scar limestone of Aldstone moor.

Millstone grit series.—The great extent of surface occupied by this thick mass of arenaceous and argillaceous deposits renders it an important element in the scenery of the mountain districts of Yorkshire. Usually seen on high ground, where the coldness and humidity of the atmosphere favours the growth of heath, sedgy grass, and mosses, and almost extirpates other vegetation, these rocks commonly form a surface of dreary moorlands, far less serviceable to the agriculturist than much loftier hills in the slate district of the lakes. Under this brown covering, the grits and shales are equally concealed, except where some torrent or waterspout has ploughed deeper than usual. But the edges of these dreary surfaces commonly shew at least the coarser grit rocks, in bold broken craggy edges, easily known at great distances from the continuous vertical 'scars' of limestone. Thus the millstone grit of Arkendale and the Ingleborough grit are seen and recognized in the brows and sides of many western mountains. The upper grit of Brimham appears in the east usually on the summits and at the prominent points of lower hills, much as in Derbyshire.

The waterfalls in the grit rocks are not numerous yet sometimes (in Arkendale and Swaledale) pleasing, though deficient in wood. The wasting power of the atmosphere is very conspicuous in these rocks: searching out their secret lamination; working perpendicular furrows and horizontal cavities, wearing away the bases, and thus bringing a slow but sure destruction on the whole of the exposed masses. The rocks of Brimham are in this respect very remarkable, for they are truly in a state of ruin, those that remain are but perishing monuments of what have been destroyed; and it is difficult to conceive circumstances of inanimate nature more affecting to the contemplative mind than the strange forms and unaccountable combinations of these gigantic masses. In their decay the works of nature have an instructive similitude to the ruins of human constructions, and suggest inquiries of the

same order. Many problems concerning long duration and successive monuments of the changes of the globe, may perhaps never be completely solved by human labour, but the very effort to reach such high points of knowledge fulfils the great object for which man is made curious concerning the works of creation: his intellectual strength is augmented by the attempt, and enabled to adopt those large and worthy views of God and nature which religion and science equally demand. What can be more congenial to the undying mind of man, than to see in all existing nature the effect of a settled order of terrestrial forces, put in action from the beginning of earthly time; to see performed to-day the phenomena provided for in plans fixed thousands of ages ago; and to speculate on future conditions of the globe, to which these phenomena are to give rise? (See Outline of part of Brimham rocks, No. 22.)

CHAPTER VI.

General Views.—Circumstances attending the Deposition of the Mountain Limestone Formation.

THE most exact details in natural science are valuable not so much for their own sake as for the solid foundation they afford for the establishment of laws of phenomena, the explanation of which is the province of theory. The search for theory, the noblest exercise of cultivated minds employed in the works of nature, would never have fallen under suspicion and prejudice, had it been conducted according to the only possible method likely to yield success. To discountenance speculations which trench on the province of observation and inference, especially in a science of such complicated relations as geology, is not only wise but necessary; but when vast multitudes of facts are gathered,—the only materials for a theory collected,—it is equally wise and necessary to employ on geological phenomena the processes of reasoning to which we are indebted for the laws of the phenomena of chemistry, and the combination of such laws in a general theory of astronomy.

For many and obvious reasons it is desirable that the task of combining local truths (the first order of inferences in geology) should be attempted by the same person who has ascertained them. To him gradations and variations are often known too minute for description yet necessary to the train of argument, and influencing rightly his own conviction; the relative value of the observations has due weight with him in clearing up discrepancies and correcting results; and thus data are made available which would be too incomplete or apparently disagreeing for other men to employ with safety. Besides it happens in geology as in other sciences, that few persons but the observer will be

at the trouble of the necessary discussions, and thus vast collections of facts become almost useless, and years of labour end with no important result.

Succession of deposits.—Fixing our attention on the most striking feature of the mountain limestone deposits of the North of England, the repeated succession of nearly similar combinations of limestone, gritstone, and shale, which constitute them, we shall find two conclusions inevitable; first, the mineralogical differences of the parts of the series of deposits must be referred to different general agencies, or local conditions; secondly, these different agencies or local influences predominated periodically. Neither of these propositions needs further proof than the mere inspection of the diagrams on p. p. 37 and 38; the successive different deposits there indicated are the effects of different agencies or conditions, successively predominating, and the repetition of such successions proves the periodical predominance of the causes. Turning next to the results already partially disclosed, p. p. 32, 46, &c. of the unequal distribution of different members and groups of strata, we find the predominance of certain strata, particularly the gritstones and shales and certain limestones, to be a limited phenomenon, spreading from certain centres or lines of principal intensity and vanishing in particular directions in a definable ratio. Hence I adopt a third conclusion, that strata and groups of strata so circumstanced are the effects of local physical conditions, while others, as the lower limestone for instance, being found with very similar characters in many parts of England, Ireland, and some other parts of Europe, appear to indicate more general and continual agencies. Yet even with respect to these more general deposits, it is sufficiently proved (p. p. 84 and 86,) that they are also locally variable and liable to lose their character of continuous deposits and to assume that of *periodicity*. Hence the primary object of theory is to discover the local centres and lines of principal intensity of the several agencies or physical conditions concerned.

Lines and centres of greatest and least thickness.—It has been al-

ready shewn that the area of the upper or Cam limestones of the Yoredale series is bounded on the south-east, by a line from Lancaster to Ryeloaf, there turning to pass under Great Whernside and along the eastern side of Coverdale. If another line be drawn from Great Whernside through Cam fell to Bow fell, it will divide the area of Cam limestone into two unequal parts; in all the northern parts both the main and underset limestones belonging to this group are developed, but on the south of the line there is only one of these limestones, (except in a narrow tract running out through Widdale fell to Wharnside.) The point of intersection of these two lines (under Great Whernside) is for this and other reasons often referred to in the following inquiries.

The lower limestone attains its greatest thickness in the region between Wharfedale and Ribblesdale: it is probably not less than 1000 feet thick in the vicinity of Kettlewell and Arncliffe. Under Ingleborough and Penyghent it is from 400 to 600 feet thick, and along the Penine chain from Kirby Stephen northwards a less thickness may be assigned to it. North of the line from Kettlewell to Bar fell the lower limestone becomes divided by beds of grit, shale, and coal, which augment continually northwards, so as at last to change altogether its character. In the Diagram, No. 24, this is attempted to be shewn in a peculiar manner. G G G being the general basis of grauwacke, and L L L a continuous circle representing the upper surface of the lower limestone, the thickness of this limestone in any direction, north, south, east, west, &c., is supposed proportionate to the interval between the two circles. In the direction of Kettlewell this is taken at 1000, in the direction of Bar fell 400. The interpolations of slate, grit, &c., are slightly marked in the northward direction, because the diagram is intended to apply only to the area between the Craven fault and the vale of the Greta.

The Yoredale rocks exhibit within this area far greater variations: under Great Whernside they are reduced to about 300 feet: and this is almost wholly limestone belonging to the lower part of the group and thicker than usual: in the direction of Fountains fell, these lime-

stones grow much thinner, and are almost lost in a mass of plates, while upper terms of the series appear. In Ingleborough the whole thickness is much augmented, but the limestones are still obscure, except the lowest and the uppermost: an equal thickness of beds appears in Wharnside, and the limestones are all complete; (the upper one thin.) In Bar fell the Yoredale series appears to be about 1000 feet thick, and all the limestones are seen except one of the upper beds. This thickness, all the limestones being complete, continues through Swaledale; but in the lower part of Wensleydale and Coverdale it rapidly contracts; the lower limestones thickening and the upper ones, with the greatest part of the grits and shales, growing thinner as the section approaches Great Whernside. These circumstances are represented in the diagram, which thus shews that in the direction where the lower group, consisting wholly of limestone, thickens, the Yoredale rocks, consisting chiefly of gritstones and plates, grow continually thinner.

The millstone grit series does not appear liable to so great variations of thickness as those just described: the very detached manner of its occurrence is also unfavourable to exact results. The lowest portion of the deposit may however be noticed. The Ingleborough millstone grit is almost in contact with the top of the Yoredale series in the vicinity of Great Whernside; but in leaving this point in any direction there is found an intervening set of plates, limestones, cherts, and sometimes coal, amounting to 40, 60, 100, and 120 feet in thickness. This circumstance is introduced into the diagram; which thus shews at a glance the principal features of the variation of thickness, &c. in the district; and indicates, as a general result, that the intensity of the agencies which produced the lower or Wharfedale limestones augmented toward the south-east, and diminished toward the north-west, while the agencies predominating in the production of the Yoredale series diminished toward the south-east, and augmented toward the north-west.

Nature of the Rocks.

The strata of the mountain limestone and millstone grit series are formed of limestone, chert, galliard, gritstone, flagstone, plate, shale, ironstone, and coal, variously combined

Limestone.—Its *chemical composition* is remarkably uniform; the thick beds of the whole series are nearly pure carbonate of lime; but thin beds buried in thick deposits of clay (as in the country of Craven) are always contaminated by considerable admixture of argillaceous matter, and generally rendered unfit for the lime burner. The crystalline varieties contain magnesia. The *aggregation* of the rock varies; it is compact, with smooth texture; granular; granular and crystalline, as in the beds and courses of dun lime; oolitic as in the vicinity of Burton in Lancashire, composed of crinoidal columns as the Cam limestone generally.

The different *colours* of the limestones offer curious subjects of inquiry; the black varieties, sometimes certainly known to contain bitumen, are chiefly confined to the vicinity of argillaceous strata; they occur at the top of the lower scar limestones alternating with plate; the Hardrow scar limestone and Simonside limestone are of dark or black colour almost universally; certain thin beds between them are also dark coloured; (these correspond to the black limestones of Craven and yield the Dent marble;) the other limestones of the Yoredale series, and the thin beds above main limestone, are sometimes dark;—black and deep blue beds lie in the midst of the lower scar limestone in Wharfedale. Red limestone occurs in the lower scar limestone at Ravenstonedale, Kirby Stephen, Kirby Lonsdale, and Kettlewell: some of the limestone of Ash fell is yellowish: white limestone abounds in the midst of the lower scar series, where the beds are thick and the structure prismatic. Perhaps the most prevalent of all the varied hues of this rock is a bluish gray, of different degrees of intensity; few beds are really blue, though the tendency to this colour increases to the northward, and the term is commonly used in

Teesdale and Aldstone moor, for beds of the Yoredale series. The main limestone is bluish in that district, but grows gray or even whitish toward the south-east. The lowest beds of Brough are smoky, yellowish, and mottled.

Specific Gravity.—Limestone lying on the grauwacke of Moughton fell, (hard, compact, and black,) 2·785; 'Dun lime', granular, and crystalline; Moughton fell 2·81; Kettlewell 2·79; Ingleton 2·77; Kirby Lonsdale (bed) 2.744; Biggin near Kirby Lonsdale 2·735. Limestone lying on the Whin sill, white and crystalline, 2·68; compact limestone of Kirby Lonsdale, Casterton, and Barbon, 2·70; red limestone of Kirby Stephen 2·597, 2·608; yellowish beds of Ash fell 2·60; sonorous limestone of Biggin 2·70. Main limestone of Ingleborough 2·66; Hardrow scar limestone 2·73; black argillaceous limestone of Pendle hill 2·69. Nearly all the dark varieties yield the disagreeable smell of swinestone on being struck or powdered.

Chert.—Composed of silica, with uncertain admixtures of calcareous and argillaceous earths: texture compact, with splintery and hackly fractures, finely granular, or laminated: colour white; gray tinged reddish, yellowish, bluish; black; mottled and shaded. Specific gravity 2·3 to 2·5. Forms beds above the main and underset limestone, in Swaledale, Wensleydale, and Bishopdale; nodules in the main limestone and underset limestone of Coverdale, &c.; narrow bands and nodules in the black limestones of Craven. It bears in these cases the same relation to limestone as flint to chalk. The light-coloured sorts are liable to decomposition, and then yield white or brownish powders, and organic remains. The chert rocks above main limestone are usually very much fissured, so as to fall to fragments on being shaken. Some varieties pass to plate, others to gritstone, others to limestone.

Plate may be viewed as a series of interrupted deposits of bituminous clay, condensed and indurated into a finely and regularly laminated rock. There is usually some oxide of iron in the mass; its colour almost uniformly black or dark gray; slightly micaceous,

and sandy; frequently carbonaceous, so as to burn with flame and leave white ashes, and calcareous so as to effervesce with acids. All the plates whiten in fire, and are bleached near the Whin sill and dykes. Specific gravity 2·45, 2·55, 2·58—altered by Whin sill Teesdale 2·66.

Shale.—The varieties of argillaceous rock, which are less finely and regularly laminated than plate, often of a lighter colour, sometimes more sandy and micaceous and less calcareous, may be ranked under this name. It belongs rather to the millstone grit than to the mountain limestone formation. Specific gravity 2·4, 2·5. Soapstone is a compact fine smooth-grained shale.

Gray beds.—Alternations of plate or shale and laminated gritstone, too numerous and connected to allow of separate nomenclature, are usefully characterized by this title, which also may comprehend such alternations as 'post and girdles,' 'girdle beds', 'stone bind,' &c. These grow more abundant toward the North of Yorkshire, and appear more frequent in the millstone grit than in the Yoredale series.

Flagstone.—A laminated rock, composed of small worn grains of quartz, mica with or without felspar, and other minerals, occasionally calcareous, carbonaceous, and argillaceous: the mica or carbon lying in particular planes causes the minute fissility of the stone, and bands of mica or argillaceous matter separate it into thin flags or beds. The tops and bottoms of gritstone rocks are often thus laminated; plates becoming very sandy change to flagstone; grit rocks becoming very argillaceous assume the same character: thus it is especially abundant in all parts of the Yoredale and millstone grit series, though its value is extremely variable. Vermicular markings, sometimes clearly of organic origin, often cover the surface, and indicate *littoral deposition.* Colour yellowish, black speckled, or white, the mica usually white and silvery. Specific gravity, Hutton roof 2·37, 2·43; Brignall 2·50; Garsdale 2·52; Dent wold 2·58; Ingleborough 2·60.

Galliard.—Very hard close grained gritstone, of which the grains are nearly confluent, and the mass partially translucent, is thus named: the term is nearly equivalent to 'Whin' of the Newcastle collieries. The ganister or calliard of the Yorkshire coalfield is a continuous rock of a similar description, but the stone more frequently occurs in nodular masses aggregated by local molecular attraction. (Probably derived from Caillou Fr. a pebble). Specific gravity, Sellet bank 2·59; Hutton roof 2·50.

Gritstone.—Composed of worn grains of quartz, adherent in various degrees, not distinctly laminated like flagstone, nor very closely aggregated, like galliard. The quartz is often mixed with mica, and sometimes agglutinated by felspar: oxide of iron and calcareous matter are variously associated with it. There are three indistinct varieties: viz. *Millstone grit,* very coarse-grained, sometimes full of quartz pebbles from the size of a pea to that of a walnut. The upper millstone grit usually contains more felspar than the lower ones, especially toward Derbyshire. *Freestone*—an equal grained rock, often micaceous, breaking in all directions equally. Hazle a hard condensed gritstone, which varies to freestone, flagstone, and chert, according to the locality. The term is peculiar to the North of England. Specific gravity of millstone grit 2·5; Freestone of Sellet bank near Kirby Lonsdale 2·30; Barnard Castle 2·375; Dockray moor 2·34; Hazle of Ingleborough 2·49; of Barbon beck 2·46; altered under Whin sill of Teesdale 2·64.

Ironstone, or argillaceous carbonate of iron, occurs in the plates of the Yoredale series, and in the shales and plates of the millstone grit, but not abundantly. It is mostly in spheroidal small nodules; but in Wyersdale (Bolland) it forms large septaria. Specific gravity 3·35. The rock so named in Teesdale and Aldstone moor is very different; it is almost a limestone in Teesdale.

Coal.—Some of the coal of the millstone grit and limestone series is merely carbonaceous and bituminous plate; and even the best bed of it (Colsterdale, Tan hill, Leyburn,) is far inferior to that common

in the coal tracts above millstone grit. It is usually sulphureous, and contains oxide of iron, but some thin layers are crystalline and pure as any other coal. Specific gravity (see page 130) according to the purity of the coal 1·29 to 1·62.

Nature of the series.—Reduced to its greatest simplicity the carboniferous system presents three leading groups, viz. coal measures, average sp. gr. 2·4; mountain limestone 2·7; old red sandstone 2·5. This is nearly exemplified in the South of England. The next modification, found in Wales, Derbyshire, and Yorkshire, admits of two intermediate transition groups, which really connect the other three into one compound system. See the Tables, p. p. 11, and 12.

As we proceed northward these groups become further subdivided, but, the number of the component substances remaining the same, a general analogy still remains, and the most complicated details are reducible to the same general scheme: thus,

Coal measures	Coal measures	
	Millstone grit	Upper millstone grit.
		Various.
		Middle millstone grit.
		Various.
		Lower millstone grit.
		Various.
Mountain limestone	Mountain limestone	Yoredale rocks.
		Wharfedale series.
	Limestone and red sandstone	
Old red sandstone	Red sandstone.	

The Yoredale series of rocks where fully developed exhibits five principal and similar terms; and several irregular terms, which may be thus arranged,

			Sp. Gr.
Main limestone, &c.	5	Limestone	... 2·6—2·7
		Grit or flagstone	2·5
		Plate	... 2·5

		Limestone ...	2·6—2·7	
Underset limestone, &c.	4	Grit or flagstone	2·5	Limestone.
		Plate ...	2·5	Gritstone.
				Plate.
		Limestone ...	2·7	Flagstone.
Middle limestone, &c.	3	Flagstone ...	2·5	Plate.
		Plate ..	2·5	Limestone.
				Gritstone.
		Limestone ...	2·7	Plate.
Simonside limestone, &c.	2	Grit or flagstone	2·5	
		Plate ...	2·5	Grit.
		Limestone ...	2·7	Plate.
Hardrow limestone	1	Grit or flagstone	2·5	
		Plate ...	2·6	

In particular places bands of plate intervene between the limestone and the gritstone, but the most prevalent type is that given above. The same character of the terms of the Yoredale series will be found in Mr. Westgarth Foster's Section of Aldstone Moor. Coal occurs with every one of the terms, but locally and somewhat irregularly, except between the main and underset lime and above and below the middle limestone. The number of these terms is found to be the same in all parts of the Yoredale series, except where it undergoes rapid changes toward Great Whernside and Fountains fell.

Variation of the terms of the Yoredale series.—Proceeding from Hawes to the south, the terms of the series change greatly: and most of the gritstones are completely lost, and the limestones diminished in thickness and debased in quality by admixture of argillaceous matter. In Ingleborough, the fourth term has no limestone, but the gritstone, one of the most continuous of the Yoredale rocks, is fully developed. Proceeding westward, the gritstones become more constantly laminated. as may be seen by comparing the sections of Hawes and Wharnside, p. p. 37, 38—northward little changes appears; eastward and south-east ward both grits and plates diminish in thickness, while the limestones grow thicker, except those of the fourth and fifth group which die away.

From all this a conclusion arises that the calcareous members of the Yoredale series (except those of the fourth and fifth terms) have their maximum toward the east, the argillaceous beds toward the south and south-west, and the grit rocks toward the north and north-west. The southern argillaceous type is prolonged into Derbyshire, Staffordshire, Cheshire, and Flintshire, and reappears in great force in the North of Ireland: with a less thickness of shales, it is represented in South Wales, Somersetshire, and Belgium. The northern argillaceous type reaches the Tweed, and spreads round the northern border of the Cumbrian slates.

The inconstant members of the terms of the Yoredale series are coal, ironstone, and chert. It is evident in considering the occurrence of these substances, in the Yoredale rocks, that ironstone is very much most abundant in the argillaceous beds, and in the southern districts; but coal on the contrary is most plentiful in the northern tracts where gritstones are more predominant. Chert becomes less and less plentiful as we leave Craven, and proceed northwards; in Swaledale and Arkendale it is found in great quantity, but does not abound further north.

Origin of the substances.—The agencies concerned in the deposition of the different substances composing the mountain limestone formation being assumed to be located in the directions of the maximum thickness of each respectively, we may proceed to investigate the nature of those agencies, by comparing in some detail the character of the several substances produced by them. The first circumstance to be dwelt upon is the distribution of organic remains.

Organic remains are found in all the terms of the mountain limestone formation, and in all the substances composing them, but very unequally. All the limestones contain marine reliquiæ; the plates generally contain marine exuviæ also, locally in the greatest possible profusion, but *seldom* where they are *sandy*, or interstratified with *thin gritstones*. The plate under main limestone contains fossils at Bowes; that under the underset limestone in Fountains fell; that under the

middle limestone in Coverdale; that under the Simonside limestone in Coverdale; that under the Hardrow limestone at Gale and Aysgill. The gritstones contain *rarely* traces of terrestrial plants: where of a cherty nature, or unusually calcareous (as in Penyghent) marine exuviæ become proportionably numerous. Organic remains are more numerous and varied in the lower limestone than in the Yoredale series. It is from this rock that the numerous fossils of Belgium, Mendip, South Wales, North Wales, Ireland, Derbyshire, and South Yorkshire are collected. Polyparia, crinoidea, conchifera, brachiopoda, gasteropoda, cephalopoda, crustacea,—all are most plentiful in the lower rock. But its great superiority in this respect vanishes away in those directions where the interpolations of gritstone and plate become frequent—as for example in Aldstone moor, and generally in Northumberland and Scotland. In the Yoredale series, the greatest abundance of fossils is found in or close to beds of limestone. Particular beds of limestone are marked (locally) by the prevalence of certain fossils: the Cam limestones (No. 4 and 5) are usually composed of little else besides fragmentary stems and plates of the bodies of crinoidea, producing the remarkable crinoidal marble of Garsdale, like some analogous but older beds in Derbyshire, Bolland, and Greenhow hill: lithodendra abound (locally) on the top of the Hardrow scar lime both in Coverdale, under Penyghent, in Wensleydale, Swaledale, and Aldstone moor: producta gigantea abounds in most localities in the upper dark layers of the lower limestone, alternating with shale, (Hawes) also in the Hardrow scar limestone, (Askrigg) and in the main limestone (Rokeby). The shells of cephalopodous mollusca are very rarely found among the rocks of the Yoredale series except in the shales below the Cam limestones. Here orthocerata, ammonites sphericus, a. striatus, bellerophon Woodwardii, naut. sulcatus, occur.

The organic remains are not at all worn; but retain all their sharp processes, spines, &c. in perfection, except in particular situations (as in the conglomerate limestone which lies on the grauwacke near Ingleton, and Horton.)

These circumstances are perhaps not sufficient to justify the conclu-

sion so generally admitted that the organic exuviæ remain on the very spot where the animals lived and died; but it would be unreasonable to imagine that they can have been subjected to much violence of water: they consequently inform us what were the inhabitants of the sea in which the mountain limestone formation was deposited.

We may next attend to circumstances likely to give information as to the *mechanical agencies* exerted in this sea. At the base of the system the old red sandstone shews by its conglomerate beds, laminated micaceous gritstones, and the fragments of land plants which lie in some of them, decided evidence of violent watery movements. The limestone resting on grauwacke betrays the same agency, in its included boulders and pebbles of slate, and disturbed corals, (Moughton scar): but the whole mass above, for several hundred feet, shews not the least trace of any such watery disturbance. We must admit, therefore, the ocean to have been here devoid of any unusual agitation during its deposition. This is fully corroborated by all that is known of the rock in other localities. The same conclusion applies to all the calcareous strata of the Yoredale series; for the fragmentary state of the crinoidal remains in the Cam limestones requires no supposition of agitation in the sea beyond that which must always have been felt along its shores.

Where not much intermixed with grits and shales the mountain limestone is pure carbonate of lime; some of the beds are crystallized; and the general tendency of observation goes certainly to establish the conclusion that this limestone is an original deposit from the waters of the ocean,—not by desiccation, but by a chemical decomposition of the fluid, arising from some widely diffused and long continued agency.

What was that agency? I can only offer a conjecture that it was a liquid or gaseous substance generated in the submarine oceanic laboratory of nature, diffused through the waters of the sea, from one or many openings on its bed, and causing similar decompositions at a nearly uniform rate through long periods of time. The precipitates thus occasioned would be liable to lateral movements corresponding to the ordinary and

unusual agitations of the sea, and would then assume the stratiform structure, most remarkably where the deposit was least thick, and the contrary.

The argillaceous members of the mountain limestone series, though equally void of any indications of violent currents, show proof in their universal fine lamination, and minutely sandy texture, of the influence of some long continued and widely diffused watery movements.

The gritstones of the mountain limestone formation appear to have been aggregated under the influence of a continual deposition of carbonate of lime; for they all contain more or less of this earth very finely disseminated among the grains of sand which compose the mass. They are usually harder, and less argillaceous, than the sandstones of the coal measures above millstone grit, and contain much less felspar. Such of them as contain an unusual quantity of carbonate of lime and argillaceous matter, disseminated among the grains of quartz, as in Penyghent and under Richmond castle, become very hard and cherty and these contain organic remains. The flagstones are always very micaceous and often carbonaceous, and associated with thin argillaceous partings. What are called gray beds, and girdles, have the same general characters. The siliceous grains of these rocks are fragments, not crystals; the mica is also in fragmentary scales; the plants occasionally found are broken; and the general tendency of all the evidence points clearly to variable watery currents from the land, excited at a considerable distance, and moderated by passing through great breadths of the ocean.

This view is strongly confirmed by the fact that the prevalence of coal seams in the Yoredale series and lower limestone is almost in the direct ratio of the abundance of gritstones in the section. While in all the great shales of Ireland, Derbyshire, Bolland, and Craven, hardly the least trace of coal is to be found, it occurs in almost every part of the Yoredale series from Wensleydale to the Tweed.

The general distinctness of the argillaceous and arenaceous bands, in those districts where they alternate, implies alternate influence of dif-

ferent currents; the greatest thickness and purity of the argillaceous deposits being to the west, and the same qualities belonging to the gritstones in the north, we may venture to suggest as an explanation the entrance of two distinct currents or primeval rivers, one on the west bearing sediment from the surface of a region of argillaceous slates, the other on the north bearing almost wholly the granular detritus of regions abounding in gneiss and mica slate; both the deposits being modified by a continuous deposition of carbonate of lime.

Where then shall we look for the surfaces of argillaceous schists thus raised above the sea, which might by wasting away yield materials for the shales of the Yoredale series of rocks? The Cumbrian slates might perhaps be imagined to have yielded, to eastward and southward currents, the argillaceous substances of the Yorkshire dales and hills of Derbyshire; the Lammermuir to have supplied these of Northumberland and Durham; but whence have come the contemporaneous and very similar shales of the North-west of Ireland? These appear to indicate more general agency; perhaps to afford ground to believe that the real source of these materials was some more western land or shore now wasted away, or again submerged beneath the sea.

The traces of the current from the north appear more and more distinctly as we proceed from Yorkshire through Aldstone moor to Northumberland: in the continual diminution of the finer and increase of the coarser varieties of gritstone. The gritstone rock below the underset limestone is in Yorkshire generally fine grained and useful for flagstone; in Aldstone moor, under the name of Nattriss gill hazle, it is decidedly much coarser in grain, and more massive in structure; further on in Northumberland it becomes a pebbly millstone grit, of greater importance in the series than any of the rocks of the true millstone grit series.

If we follow this indication and look to the north for the local origin of the current which brought the arenaceous deposits of the mountain

limestone series, the Lammermuir must be passed by for its argillaceous materials are not of the nature required; the Grampians, in this respect more suitable, can scarcely be admitted as the source of such rocks, else why do they not occur abundantly along its borders, and constitute a prominent feature among the Scottish limestones? It is obvious that further inquiry would be of little value; geology rejects conjecture; but whether we imagine the materials to have drifted from the uplifted Scandinavian Peninsula or from some ancient land or coast now lost in the ocean, the impression left on the mind is that great and extensive convulsions have since totally deranged the physical geography of the regions, and left no sufficient evidence for the guidance of a prudent theorist, in endeavouring to restore the lost hydrography of the sea which flowed above the mountain limestone deposits.

These conclusions apply to the mountain limestone formation, let us see what can be learned of the millstone grit series by a similar investigation.

The *greatest thickness* of the millstone grit series is found in Yorkshire; it occurs in Nidderdale, Colsterdale, and about the head of Wensleydale and Swaledale, as the details previously given have sufficiently made known. To the south of the line from Great Whernside to Bar fell, the series of millstone grit rocks, shales, and coal beds, appears to suffer condensation, and upon the whole to grow thinner, though the coarse pebbly rocks which characterize the series are even more abundantly deposited. Northward from Swaledale the whole series grows gradually thinner, the pebbly gritstones diminish and grow less important, so that in the north-western parts of Northumberland it is doubtful whether they are worthy of a separate place in the scale of stratification.

The greatest variety of substances occurs in the same parts of the country where the whole series has the greatest thickness; perhaps the line of greatest variety may be drawn from Nidderdale head through Water crag.

The millstone grit series grows thin round the north side of the Cumbrian slate mountains; this does not appear to be the case on the south side; portions of it are thick in Derbyshire, but in all the southern parts of England and Wales, and in Belgium and Westphalia, the whole series is reduced to obscure and unimportant traces. In the North-West of Ireland it is considerably developed, but in Arran and Scotland hardly known at all.

These observations appear to prove that the agencies concerned in producing the millstone grit series were not geographically posited like those which occasioned the grits and shales of the Yoredale rocks; but not sufficient to justify any further speculation on their origin.

Time elapsed.

It is too difficult a problem for the present state of geology to determine the length of time which was consumed in the production of any given set of rocks: upon particular suppositions, comparative results might indeed be obtained, as I have shewn in the Encyclopædia Metropolitana, but these speculations belong to general not local geology.

Depth of Ocean.

This is another very interesting branch of inquiry too obscure to be followed out with any reasonable hope of success, except in a general discussion of geological theory. Too little is known of the distribution of recent organic forms in the sea, to justify the adoption of general rules, relating to the depth at which they live: and even were this not the case, the almost total dissimilitude between recent species and those of the mountain limestone would prevent our applying them. No certain conclusion can be drawn from the nature of the deposits, though, compared with other formations they appear to indicate considerable depth, and, unless from general views concerning the elevation of the strata from the bed of the sea, there appears at present little hope of throwing real light on this matter.

Elevation of Lands.

The evidence of subterranean disturbances and partial elevations, contained in a former chapter, still leaves untouched one important object of general research, viz. the elevation of the mountain limestone district *above the level of the sea.* The Penine chain suffered elevation and with it the whole Penine region was uplifted; but since that æra red sandstone beds were deposited in a sea flowing round the hills of limestone and gritstone, and these have in their turn been raised above the sea; how was this effected? This question is not of local interest merely, it applies, with suitable conditions, to the whole surface of red sandstone in England; and is to be repeated for almost every succeeding formation. Accustomed to admit the effects of local elevation, it seems easy to ascribe to similar agencies the more extensive effects now contemplated: lines and axes of convulsion may be imagined sufficiently numerous and effectual to elevate the whole island: but this hypothesis will not bear a moment's examination, for these axes and centres are indeed *imaginary.* Hardly the least trace of such appears in the red sandstone of the plain of Carlisle, or the great central red sandstone field of England. Only two possible causes remain for consideration, an extensive abstraction of the ocean, or an extensive elevation of its bed. The ocean can not have been lowered *here* to the extent required in this case (see my Guide to Geology) in consequence of any supposed displacements of land *in other situations,* consistent with reasonable views of the constitution of our planet: neither will any assumed general changes of temperature of land and water satisfy all the conditions: we have therefore finally to choose between gradual and extensive elevation of the land, and extensive abstraction of the ocean to other situations on the globe, in consequence of some alteration in the earth's axis or other great physical catastrophe.

For many reasons we should hesitate to adopt the latter view; the former hypothesis is recommended by its agreement with the leading truth contained in all inferences concerning ancient subterranean movements; and it is supposed to be actually a cause still operating in the

northern zones of the globe. (See Mr. Lyell on Elevation of Land in Scandinavia, Phil. Trans. 1835.) Admitting then the gradual elevation of the district in question after the production of the numerous sudden dislocations already described, let us inquire whether these phenomena can be referred to any general cause. Have the disturbing movements been caused by forces acting *towards* the centre, or *from* the centre of the globe? by a general cooling of the surface and consequent *collapse* of the strata, or by local violence of subterranean chemical excitement? The phenomena of one district certainly are insufficient to decide such a question, but as general inferences in geology can only arise from combining local truths, the tendency of the evidence in this region must be stated.

A general collapse of the strata of the globe in consequence of refrigeration of the subterranean regions, would bring the spherical area corresponding to one radius of the globe into the space corresponding to a shorter radius: the consequence would be not only fracture but bending of the superficial beds, until the adjustment were completed, and the lateral and vertical pressures balanced. On the contrary, expansion of the surface of the globe should be expected to leave traces of the stratified masses being borne to situations where they would not occupy the whole space, and bending strata indicative of lateral strains should be rare and exceptional. The greater part of the phenomena appear favourable to the view of the disturbances being accompanied by general contraction of the globe: the whole Ribblesdale system consists of undulations indicating lateral pressure; and it is frequently seen among the faults of the Penine region that the dislocated beds bend upwards or downwards to the plane of the fault. The same is the case in many of the faults of the Newcastle coalfield. (See Diag. No. 18.)

It is remarkable, and by some geologists thought confirmatory of this view, that in the south-western part of the district in question, and along a considerable portion of the western coast of England and Wales, beds of marine shells in sand and gravel have been found under

such circumstances as to prove that the elevation of considerable tracts of land above the sea in those parts (near Preston, in Cheshire, and on the Snowdon range) has happened since the creation of the species of Testacea now living on the shores. Evidence is not wanting on the east coast of Scotland and England, and on the east coast of Ireland, to prove a similar variation of the level of land and sea, (independent of cataclysmal accidents,) and perhaps, eventually, it may appear certain that the elevating process, if now ended, was continued under a great part of the British Islands till a late geological period. If this should be admitted, the extraordinary phenomena of the dispersion of the Cumbrian rocks to the east will still require the operation of great and violent oceanic currents excited by sudden subterranean movements, but the dynamical difficulties of the problem will be so much reduced, as perhaps to bring it within the scope of an inquiry into the possible extent of watery currents producible by displacements of the crust of the globe, and thus to permit on good grounds the union of sudden dislocations, gradual changes of level, and distant cataclysms, in one point of view, as necessary results of the slowly changing temperature of the globe.

CHAPTER VII.

Description of the Fossils in the Mountain Limestone Formation of Yorkshire and of some other districts, arranged according to their Natural Affinities; with Notices of the Strata in which each species occurs, and of the Localities where they are found.

REMAINS OF PLANTS.

These are distributed through the whole thickness of the system of carboniferous strata, which is above 6000 feet, but very unequally; so that while 200 species are already described from the upper or coal measure formation, not ten have yet occurred to me in the millstone grit series, and still fewer in the sandstones and shales alternating with the mountain limestone. It does not appear that the species of plants are very characteristically different in these different stages of the carboniferous deposits; for the same stigmariæ, lepidodendra, and sigillariæ, are certainly found in all parts of the series. There is however to be noticed a greater prevalence of certain forms in strata occupying a given position, and a remarkable absence of other forms from particular parts of the section. Thus stigmaria ficoïdes, though it occurs in all parts of the series, is in a singular degree abundant in connexion with a few layers of fire clay and close grained gritstone near the base of the coal measures. The numerous species of pecopteris, neuropteris, and other ferns, belong almost absolutely to the coal measures, (exceptions occur at Burdiehouses near Edinburgh and in north-west of Northumberland), stems of sternbergia abound in certain beds of millstone grit, and calamites, at least in Yorkshire, are most plentiful in and near the flagstone rock. In a very limited coal tract, some definite diagnostic characters of coal seams may be noticed, in accordance with Mr. Mammatt's observations in the Ashby

coalfield, and with Mr. Smith's minute distinctions between the members of the Bath oolite formation; but these *local truths* lose their force when applied to other districts. Geologists, and especially those who describe particular tracts of country, do not sufficiently keep in view the distinction of *local facts* depending on limited geographical circumstances, and *general phenomena* caused by extensively uniform conditions in the ancient world. Yet on this distinction rests the difference between the knowledge of his *art* possessed by a miner, collier, and quarryman, and the *science* which it is the business of a geologist to advance. That the same species of plants are repeated in many stages of the coal measures is fully ascertained by Mr. Hutton's researches in the Newcastle coalfield, and my late friend Mr. E. S. George of Leeds and myself vainly tried to arrive at a different conclusion with regard to the Yorkshire coalfield. We shall find similar results in surveying the other classes of organic remains.

Marine plants are almost unknown in any of the North of England carboniferous deposits older than new red sandstone, though one has been noticed by Dr. Thompson (Report of British Association, 1834), in a coal deposit near Glasgow.

Very few, and those perhaps doubtful, purely aquatic plants have been seen by any observers in these strata; it is indeed imagined by Steinhauer, and the opinion is countenanced by Lindley and Hutton, and partially by Brongniart, that stigmaria was a repent subaqueous or mud plant, and the dissected fibres of myriophyllites of Artis certainly remind us of submersed vegetation.

REMAINS OF ZOOPHYTA CUV.

Few of the mountain limestone districts of England are deficient in remains of corals, crinoidea, &c., whether as in Derbyshire and Mendip we contemplate one (the lower) thick mass of calcareous rock, or as in the north-west of Yorkshire and in Northumberland examine the thinner portions which alternate with shales, gritstones, &c. In the latter dis-

tricts crinoidal fragments are not uncommon in particular parts of the shales, shaly gritstones, and cherts, small foraminated and reticulated corals also occur in them; but the lamelliferous corals are almost wholly confined to the limestones. Several of the same species are common in the whole range of the formation, and, perhaps, if the local catalogues were more complete and more correct, it is probable that a very general conformity would be found to prevail in this respect.

None of the zoophyta has yet been seen in the proper coal measures above millstone grit, a circumstance which, combined with the partial occurrence of them in the shales and grits below, and the almost universal abundance of them in the limestone group, appears to add a strong negative proof to the affirmative evidence of fluviatile genera of shells, of the fresh water deposition of most of the coal strata.

POLYPARIA.

RETEPORA. This genus occurs in the limestones, cherts, and shales from the beds alternating with old red sandstone to the upper millstone grit. The openings in the net work are called *fenestrules*, the spaces between the ends of these *dissepiments*, those between the lines of fenestrules *interstices*. In all the figures *n* signifies nat. size.

R. membranacea. Ph. Pl. I. fig. 1 to 6. Bolland; Kildare County.

Interstices straight, equidistant; fenestrules elongated-oval; dissepiments thick; pores a little oblong, not prominent. 1 a conical specimen; 2 its external face magnified; 3 still farther magnified to shew the carinated interstices; 4, 5 the reverse granulated; 6 cast of the reverse.

R. flabellata. Ph. Pl. I. fig. 7 to 10. Bolland; Harrogate; Richmond; Hawes; Middleham; Kirby Lonsdale; Brough; Kildare.

Interstices straight, mostly equidistant; fenestrules elongated, rectangular, equal; dissepiments very thin; pores small, prominent; reverse of the interstices striated: 7 small portion; 8 the reverse striated; 9 the obverse; 10 interstices and prominent pores.

R. flustriformis. Ph. Pl. I. fig. 11, 12. Bolland; Harrogate; Richmond; Florence Court, near Enniskillen.

Fenestrules oval, in quincunx: I have not been able to see the obverse face.

Millepora flustriformis Martin Pet Derb. 43 and 45 * is perhaps the same species, but his figures are too imperfect to decide. (Middleton and Buxton.) It resembles retepora antiqua, Goldfuss ix. 10.

R. irregularis. Ph. Pl. I. fig. 21, 22. Florence Court.

Fenestrules oval; interstices somewhat irregularly set with few large oval pores.

R. tenuifila. Ph. Pl. I. fig. 23, 24, 25. Florence Court.

Interstices and dissepiments thin; fenestrules rectangular; pores (fig. 25) small with prominent edges; reverse (fig. 24) striated.

R. undulata. Ph. Pl. I. fig. 16, 17, 18. Harrogate; Bolland; Hawes.

Interstices very thin; fenestrules large irregular; pores large prominent; reverse striated. It resembles gorg. antiqua, Goldfuss xxxvi. 3, but is distinct.

R. nodulosa. Ph. Pl. I. fig. 31, 32, 33. Whitewell in Bolland; Greenhow hill; Harrogate.

Radiating, ramifying; dissepiments thin; fenestrules arcuato-quadrate; pores usually one at the middle, undulating the margin, and one at each dissepiment; smaller pores in the interstices.

R. polyporata. Ph. Pl. I. fig. 19, 20. Florence Court.

Interstices thick; fenestrules large, irregular; pores numerous, small, round. This somewhat resembles retepora cyathiformis, Goldfuss ix. 11.

R. laxa. Ph. Pl. I. fig. 26, 30. Whitewell; in Kildare.

An irregularly open net work; interstices round, bearing on the reverse (28, 29) oval spaces in quincunx, and interjacent lines of very minute pores. In a specimen from Whitewell I raised a portion and found two rows of tubular pores on the obverse (fig. 30). It resembles gorg. ripisteria, Goldfuss vii. 2. 26 is from Kildare, in the collection of Rev. S. Smith, Trin. Coll. Dublin. 27 from Whitewell. I suppose them identical but not having found the obverse in Mr. Smith's specimen can not affirm it.

R. pluma. Ph. Pl. I. fig. 13, 14, 15. Whitewell in Bolland; Greenhow hill; Florence Court.

Penniform; branches and branchlets round; two rows of large alternate pores; reverse striated.

MILLEPORA.—This genus occurs very sparingly, in lower limestone; Yoredale limestones, cherts, and shales; also in millstone grit cherts.

M. rhombifera. Ph. Pl. I. fig. 34, 35. Bolland.

Branches cylindrical, with acute rhomboidal cells in quincunx.

M. interporosa. Ph. Pl. I. fig. 36, 39. Whitewell; Pateley bridge; Harrogate; Florence Court.

Branches round, somewhat uneven, cells oval with interjacent pores. On some specimens (39) the interjacent pores are very regularly placed, on others (38) more scattered.

M. spicularis. Ph. Pl. I. fig. 40, 41, 42. Whitewell.

Dichotomous, branches attenuated; cells prominent, apertures oval.

M. oculata. Ph. Pl. I. fig. 43 to 46. Whitewell; Florence Court.

Branching at right angles; round; cells in longitudinal (or spiral) lines, very prominent; apertures oval, annulated (46).

FLUSTRA? parallela. Ph. Pl. I. fig. 47, 48. Whitewell.

Linear; longitudinally and deeply furrowed; cells in the furrows, in quincunx, their apertures oval, prominent; (side furrows without cells.) It appears to have been a tubular or folded membrane; the number of rows of cells varies in different specimens. No sign of ramification.

CERIOPORA verrucosa. Goldfuss x. 6. A species *like this* occurs at Florence Court.

GORGONIA? Pl. I. fig. 65. Bolland.

This is the only fragment which I have seen from the mountain limestone, which could be referred to gorgonia.

FAVOSITES.—This genus is found in lower scar and Yoredale limestone. It differs from calamopora by having no lateral tubules, or pores.

F. capillaris. Ph. Pl. II. fig. 3, 4, 5. Gordale; Ribblehead, &c.

Mass spheroidal; prismatic tubes very small; septa symmetrically arranged in the different tubes. 3 general appearance of the coral; 5 the terminal cells; 4 the section showing the septa and lamellæ of growth.

F. septosus Flem. Pl. II. fig. 6, 7, 8. Lee, in Northumberland; Bristol.

Prismatic tubes larger; interstices thin; septa rather irregularly arranged in the different tubes. 6 general appearance; 7, 8 sections shewing the septa, &c.

CALAMOPORA.—It is found mostly in laminar limestones, cherts, and shales, from the Brough limestone to the upper millstone grit.

C. tumida. Ph. Pl. I. fig. 49 to 57. Harrogate; Greenhow hill; Brough; Kirby Lonsdale; Middleham; Florence court; Arran.

Irregularly ramified and swollen; formed of concentric layers of prismatic cells, contracted to a smaller opening at the surface. Transverse tubuli appear to stand on the angles 53; the concentric layers of cells are separated by a lamina 54; the ostiolæ are seen in various states at 50, 51, 56, 57. It appears that this variety depends on the covering of the surface. α. ostiolæ equal and very small. β. unequal and larger (allied to calamop. fibrosa, G. xxviii. 4.)

C. incrustans. Ph. Pl. I. fig. 63, 64. Bolland.

Incrusting, cells short, transverse tubuli in rows.

C. dentifera. Ph. Pl. I. fig. 58, 60. Bolland.

Incrusting; apertures of the cells with spicular edges.

The following species probably do not belong to the genus: but I know not where better to place them.

C. parasitica. Ph. Pl. I. fig. 61, 62. Bolland.

Incrusting; cells large, open, irregularly perforated.

C. tenuisepta. Ph. Pl. II. fig. 30. Bolland; Mendip.

Inversely conical, (proliferous); cells unequal, deep, rounded within, with indistinct radiating striæ; walls perforated toward the margins. It closely resembles cyath. quadrigeminum. Goldfuss xviii. 6, (Org. Rem. v. 9.)

C. megastoma. Ph. Pl. II. fig. 2, 9. Bolland.

Incrusting; expanded; cells excavated, rounded within, and striated from the centre; with many lateral perforations near the edges.

SYRINGOPORA.—I have not seen any specimens except from the lower scar limestone series.

S. geniculata. Ph. Pl. II. fig. 1. Ash fell; Mendip.

Radiating, often flexuous, branching, round tubes, united by very numerous small transverse subverticillate tubules. (Park. Org. Rem. Vol. ii. Pl. 1, figures this. The transverse ridges vary. Fleming refers to this figure as tub. catenata of Martin, which is a different species.)

S. ramulosa. Goldfuss. Ph. Pl. II. fig. 2. Bolland; Kirby Lonsdale; Ash fell; Mendip. (Olne, *Goldfuss.*)

Parallel or flexuous tubes, irregularly united by the tubuli. (Org. Rem. t. 3, f. 1.)

S. reticulata. Goldfuss, t. 25, fig. 8; Mart. t. 42. Ashford: (Olne, *Goldfuss.)*

Small parallel tubes, connected by tubuli, alternating at regular distances.

S. laxa. Phil. not figured. Ash fell; Derbyshire.

Very loosely branched, variously coalescing with few or no connecting tubuli.

CYATHOPHYLLUM.—This beautiful genus is almost confined to the lower scar limestone series.

C. regium. Ph. Pl. II. fig. 25, 26. Lofthouse in Nidderdale; also in Pembrokeshire; the Wrekin? Derbyshire.

Composed of aggregated short prismatic radiated masses, ending in unequal angular stars: interstices tubercular: star concave in the middle, with an oval central convexity, flat or concave toward the borders: alternately long and short lamellæ 96 to 140? very sharp, the marginal ones ending within the edge of the concavity, the others proceeding *to a central line.* Nearly allied to C. hypocrateriforme, Goldfuss xvii. 1,

but has more lamellæ; also to C. helianthoides xx. 2, but the central hollow is larger, and the whole disk more concave.

C. crenulare. Ph. Pl. II. fig. 27, 28. Clithero; Mendip; Bristol; Derbyshire.

Hemispheric or discoid; stars angular, concave, the limb flat, rising to a thin crenulated margin, and sinking to a deep oval cup in the centre, which bears in the middle a conical (twisted) umbo, rarely proliferous; lamellæ about 48; alternately long and short. (It seems analogous to both C. ananas and C. hexagonum Goldfuss, but C. hexagonum has *equal lamellæ*,—ours unequal.)

C. floriforme. Martin, t. 43, appears to be different from C. crenulare; it occurs in Bolland.

C. basaltiforme. Ph. Pl. II. fig. 21, 22. Ribble head; Moughton scar; Hesket-Newmarket; South Wales; Wrekin.

Composed of adherent prismatic or pyramidal tubes, striated longitudinally, and undulated transversely; lamellæ 36, 50; the marginal lamellæ commencing within a thin crenulated vertical dissepiment. (Lithostrotion striatum, Park. Flem.)

HYDNOPORA?—cyclostoma. Ph. Pl. II. fig. 9, 10. Northumberland.

Incrusting shells; all the exposed surfaces covered with vermicular ridges, or insulated points: in the large circular cells they form radiating lines (magnified in fig. 10.)

LITHODENDRON.—In lower scar and Yoredale limestones. All the species have concave cells, and a prominent central umbo or axis, (generally oval in the section) the lamellæ are generally twisted or extinct near the centre.

L. sexdecimale. Ph. Pl. II. fig. 11, 12, 13. Kirby Lonsdale, Kettlewell; Penyghent; Aldstone moor; Northumberland; Veynal.

External tube thick, $\frac{1}{10}$ inch diam.; medial lamellæ, 15 or 16; arched vertical dissepiments.—The external tube sometimes is, sometimes not striated.

L. irregulare. Ph. Pl. II. fig. 14, 15. Ash fell; Northumberland, &c.

External tubes thick, $\frac{1}{3}$ inch diam., often coalescing; medial lamellæ 18, 20; three of these usually united in a singular manner; marginal lamellæ rudimentary. (Org. Rem. vi. 3 and 7.)

L. fasciculatum. Ph. Pl. II. fig. 16, 17. Ribblesdale; Teesdale; Ash fell; Bristol; Northumberland.

External tube flexuous, striated; $\frac{1}{4}$—$\frac{1}{3}$ of an inch diameter; an internal tube uniting the lamellæ, 24 to 26 within, 48 to 52 without. Mad. cæspitosa Martin,

t. 17, appears to be the same. Goldfuss has the same name for a different species. I have therefore adopted Dr. Fleming's name. (Org. Rem. vi. 8.)

L. longiconicum. Ph. Pl. II. fig. 18. Kulkeagh mountain; Florence Court.

External tube smooth (unless decorticated); transversely striated. Lamellæ 64, alternately longer and shorter, acute. Forms immense masses.

L. sociale. Ph. Pl. II. fig. 19. Settle.

Tubes often adherent; equally striated; transversely undulated; ½ inch diam.; lamellæ 64, alternately longer and shorter for a space round the axis, which is oval; dissepiments regularly concentric. (Martin's figure of M. duplicata has some analogy with this.) (Org. Rem. vi. 9.)

Turbinolia fungites. Auct. Pl. II. fig. 23. Bolland; Ribble head; Penyghent; Bowes; Hawes; Coverdale; Brough; Ash fell; Orton; Northumberland; Durham; Derbyshire; Bristol; (Florence Court; Stradone; Ireland.)

When young obliquely conical; with age growing bent, undulated and elongate; surface striated; star concave; a central excavated umbo; lamellæ about 120 (but fewer when young) the marginal ones very short, toward the centre discontinuous when old. (Org. Rem. Pl. iv. fig. 8, 13, 14.) It occurs in almost every bed in the whole limestone series.

Amplexus Sowerbii. Ph. Pl. II. fig. 24. Bolland; Kettlewell; Menai Bridge; Isle of Man; Ireland, &c.

Cylindrical, external tube longitudinally and transversely striated; septa regular, equidistant, plane (one nearly central depression), with crenulated edges. The tube is like a shell, its longitudinal striæ correspond to the number of the lamellæ, half this number appears on the cast of the interior. The interseptal spaces resemble the cavities of an orthoceras,—but it is truly a lamelliferous coral, *without central axis*. (Amplexus coralloides Sow.)

CRINOIDEA.

Though there are many things in Mr. Miller's arrangement and nomenclature of crinoidea which require correction, the following short descriptions are framed to agree with his system, as far as possible. Mr. Gilbertson's rich collection is the source from which almost all my drawings and examinations have been taken. In the distinction of species there is great difficulty; it is almost impossible to refer all the columns to their corresponding bodies: the variations depending

on age and other circumstances are not understood. Besides the species noticed in the following classification, Mr. Gilbertson possesses others and is likely to discover more; his collection is also very rich in varieties and malformations; and I hope that he may hereafter be induced to give to the world the result of his very diligent study of these beautiful fossils.

PLATYCRINUS.—This genus is, I believe, in England, confined to the mountain limestone series.

P. lævis? Miller, Pl. III. fig. 14, 15. Bolland; Bristol.

Pelvis saucer-shaped; surface smooth. It is very doubtful whether this be really the species of Miller: the articulations of the scapulæ do not quite agree.

P. microstylus. Ph. Bolland.

Surface smooth; pelvis larger and more conical than in the last; columnar adherence *very small*.

P. granulatus. Miller, Pl. III. fig. 16. Bolland; Mendip.

Scapular articulations small and marginal.

P. tuberculatus. Miller, Pl. III. fig. 17. Bolland; Mendip.

Truncato-cylindrical; plates tuberculated in rows; sutures sulcated; scapular articulation large and low.

P. rugosus. Miller, Pl. III. fig. 20. Whitewell in Bolland; Caldy Island; Mendip.

Pelvis and scapular plates rudely massive; scapular articulations large and low.

P. ellipticus. Ph. Pl. III. fig. 19, 21. Alport in Derbyshire; Bolland.

The interscapular plate not so long as in others. Plates radiato-tuberculate, with raised borders and sulcated sutures.

P. laciniatus. Gilb. Pl. III. fig. 18. Bolland.

Very like the last; plates tuberculato-laciniate at their edges; scapular articulations small and marginal; columnar adherence prominent.

P. gigas. Gilb. Pl. III. fig. 22, 23. Bolland.

Proboscis elevated, central; pelvis broad; scapulæ broad; interscapulars *very* unequal. It grows much larger.

P. elongatus. Gilb. Pl. III. fig. 24, 26. Bolland.

Pelvis conical; scapulæ much elongated. The specimen has an interscapular plate attached to the pelvis.

P. contractus. Gilb. Pl. III. fig. 25. Bolland.

Pelvis tapering, acute; scapulæ narrowing above; column very slender.

POTERIOCRINUS.—The pelvis of this genus was unknown to Miller. It may be described as a tripartite? supracolumnar joint, having its upper face marked with five ridges and hollows for the reception of the five costals (pelvis of Miller). See Pl. IV. fig. 20. The upper columnar joints enlarge in diameter, but diminish in thickness, and a considerable number of them are anchylosed so as to form a conical base to the pelvis. The alimentary canal is pentagonal, not round as Miller states. A young specimen is figured to shew the arms in the rudimentary state. Pl. IV. fig. 5, 6. The plates of the body are all clearly defined except the second costals (Miller) which are *only partially divided across.*

P. impresus. Ph. Pl. IV. fig. 1. Whitewell; Bristol; Arran.

Conical: angles of the plates indented; scapular articulation lunulate, excavate, ⅔ of the breadth of the plate. Pelvis thin.

P. conicus. Ph. Pl. IV. fig. 3, 7. Bolland.

Conical, contour rather pentagonal; scapular articulation the whole breadth of the plate, emarginato-pentagonal, level.

P. granulosus. Ph. Pl. IV. fig. 2, 4, 8, 9, 10. Bolland; Belmore mountain, near Enniskillen; near Kirkaldy.

Hemispherical, delicately granulose, sutures grooved; scapulæ very wide, their upper surface articulating by the whole breadth of the plate, ovato-lanceolate, emarginate within.

P.? nobilis. Ph. Pl. III. fig. 40. Bolland.

Mr. Miller named Mr. Gilbertson's noble specimen of this cyathocr. tuberculatus, and under this name it has been beautifully figured by Mr. J. Sowerby. But it does not belong to that genus. The interscapular plates are remarkable.

P.? Egertoni. Ph. Pl. III. fig. 39. Florence Court; Hawes.

First costals (pelvis of Miller) pentagonal; the whole series of plates from thence to the cuneiform base of the fingers similar; fingers ten, short; surface granulated. Column granulose, with moniliform joints and crenulated sutures: some specimens have equal, others unequal joints. This beautiful species is abundant at Florence Court, where it has been collected by Lord Cole and Sir P. Egerton. The anchylosed upper joints of the column make it somewhat resemble the figure of eugeniacrinites (Miller), but it is really allied to poteriocrinus.

The following species belong to new genera.

EURYOCRINUS concavus. Ph. Pl. IV. fig. 14, 15. Bolland.

Pelvic opening pentagonal; arrangement of plates like encrinus, internal cavity very large.

SYNBATHOCRINUS conicus. Ph. Pl. IV. fig. 12, 13. Bolland.

Pelvis anchylosed?

CYATHOCRINUS distortus. Gilb. Pl. III. fig. 34. Bolland.

Pelvis slightly conical, costals tumid; proboscis lateral; scapular articulation narrow. One specimen has six scapular articulations.

C. quinquangularis. Miller, Pl. III. fig. 30, 31, 32. Bolland; Greenhow hill; Coalbrookdale.

Pelvis very conical; column pentagonal, the joints alternately thicker, their surfaces with a striated border.

C. ornatus. Ph. Pl. III. fig. 36, 37. (Platycrinus striatus? Miller) Bolland.

Pelvis conical; the plates granuloso-striate in lines converging to the middle of the plate, a deep groove or double pit at the top of each plate.

C. mammillaris. Ph. Pl. III. fig. 28. Bolland.

Pelvis flat or convex; costals very tumid; scapular plates very large, with a broad articulation; surface granulated.

C. calcaratus. Ph. Pl. III. fig. 35. Bolland.

Costal plates tubercular or spur-like; scapulæ moderate in size.

C. bursa. Ph. Pl. III. fig. 29.

Pelvis impressed; costals large and extremely tumid; scapulæ smaller, with a narrow articulation.

C. conicus. Ph. Pl. III. fig. 27. Bolland.

Obliquely conical; pelvis large, surface granulose.

ACTINOCRINUS.—Nearly all the species of this genus belong, I believe, to the mountain limestone.

A. 30—dactylus. Miller, Pl. IV. fig. 16. Bolland; Broughton in Craven; Mendip; Kildare; Bristol; Florence Court.

Are there really more than 20 fingers to this species? I believe that I have never seen an indication of the lateral third finger of each hand.

A. polydactylus. Miller, Pl. IV. fig. 17, 18. Bolland; Mendip; Caldy I.

Smaller than the last; four or five fingers to each hand.

A. Gilbertsoni. Miller, M.S. Pl. IV. fig. 19. Bolland.

Costals shorter and wider than in the other species; their surface corrugated.

A. tessellatus. Ph. Pl. IV. fig. 21. Near Frome, Somerset.

Scapula heptagonal.

A. globosus. Ph. Pl. IV. fig. 26, 29. Bolland.

Globular, base concave; all the plates convex; ten equidistant arms? (Not A. tesseracontadactylus. Goldf.)

GILBERTSOCRINUS. New genus. Basal joints five, forming a pentagon; suprabasal five, hexagonal, forming a decagon with five reentering angles from which proceed five heptagonal first costals, and five hexagonal second costals, bearing a pentagonal scapula supporting joints which combine into round arms perforated in the centre. First intercostals pentagonal. The following species have been usually referred to Rhodocrinus (Miller)—from which, as it appears to me, they differ entirely. I dedicate the genus to Mr. Gilbertson, whose name will ever be honourably associated with the crinoidea.

G. calcaratus. Ph. Pl. IV. fig. 22. Bolland.

Base concave; all the plates convex; ten prominent tubercles round the base, five of these very large.

G. mammillaris. Ph. Pl. IV. fig. 23. Bolland.

All the tubercles mammillary; on the base ten larger than the rest.

G. bursa. Ph. Pl. IV. fig. 24, 25. Bolland.

Subglobose; base concave; all the plates convex.

PENTREMITES.

* Pelvis conical. (Ovaria absent?)

P. inflatus. Gilb. Pl. III. fig. 1, 2, 3. Bolland.

Balloon-shaped; ambulacra narrow; poriferous plates crenulated.

P. acutus. Gilb. Pl. III. fig. 4, 5. Bolland.

Pyramidal, five angled; ambulacral spaces wide and short. In fig. 5, the ambulacral plates are partially removed, in fig. 5* completely.

P. pentangularis. Gilb. Bolland.

Miller has figured it as a platycrinus and *added arms!*

* * Pelvis flat or concave; ovaria five, one larger than the rest.

† Suture of scapulæ medial.

P. ellipticus. Sow. Pl. III. fig. 6, 7, 8. Bolland.

Profile elliptical; contour pentagonal.

P. orbicularis. Gilb. Pl. III. fig. 9. Bolland.

Globose, ambulacra narrow, approximate at the base.

† † Suture basal.

Derbiensis. Sow. Pl. III. fig. 10. Grassington; Derbyshire.

† † † Suture apicial.

P. oblongus. Gilb. Pl. III. fig. 11, 12. Bolland.

Ambulacra broad; interambulacral areæ concave, longitudinally striated.

P. angulatus. Gilb. Pl. III. fig. 13. Bolland.

More globular than the last; ambulacra approximate at the base.

ECHINIDA.

CIDARIS vetusta. Ph. Ravenstonedale; Whitewell; Northumberland; Coalbrookdale; Florence Court. (The spine is rudely muricated.)

C. glabrispina. Ph. Northumberland. (The spine is smooth.)

New genus. Bolland; Ireland.

REMAINS OF MOLLUSCA CUV.

In presenting the following catalogue of remains of mollusca, it is difficult to avoid recalling to the attention of the reader the state of opinion formerly prevailing on the subject of the animal remains in the older strata. It is within the limited range of the author's memory that the notion of the existence in the mountain limestone of such genera as isocardia, nucula, pecten,—patella, turritella, and buccinum, would have been instantly rejected as something highly improbable; few persons even at this day are prepared to admit the existence of above thirty species of ammonites in the carboniferous æra; and it will take some time to dissipate the false conclusions which have been entertained concerning this subject by those who have seldom seen any of the fossils except the brachiopoda and cephalopoda. These are indeed still the characteristic forms for nearly the whole of the calcareous parts of the system, but in several districts, which from various reasons are inferred by the author to have been littoral deposits, they are mixed with a large proportion of species of other families. I have seen no ostreæ in this series.

The coal formation has abundance of unioniform shells: the mountain limestone and millstone grit almost none of them. Nearly all the species known in the whole system are peculiar to it.

CONCHIFERA PLAGIMYONA.

SANGUINOLARIA? angustata. Ph. Pl. V. fig. 2. Bolland.

Transversely depressed, elongated, diagonally carinated, hinge straight; with furrows parallel to the margin.

Sanguinolaria ? tumida. Ph. Pl. V. fig. 3. Kildare ; Bolland ; Coalbrook dale ; Kirby Lonsdale.

Transversely elongated, diagonally gibbous, hinge straight ; shell imbricated. In the cast the posterior side is marked by strong ridges from the beak (not well seen in this figure, which is reduced from a large Irish specimen.)

Sanguinolaria ? arcuata. Ph. Pl. V. fig. 4. Harelaw, Northumberland.

Transversely elongated, oval, hinge arched, surface smooth.

Sanguinolaria ? sulcata. Ph. Pl. V. fig. 5. Northumberland.

Transversely oval, depressed ; ends rounded ; surface with transverse furrows which become broad wrinkles on the posterior side ; obsolete longitudinal striæ. (Hiatella sulcata Fleming ?)

Solemya primæva. Ph. Pl. V. fig. 6. Northumberland.

Transversely elliptical, depressed, with radiating smooth striæ.

Corbula ? senilis. Ph. Pl. V. fig. 1. Castleton ; Bolland ; Colsterdale.

Transversely ovate, gibbous, hinge line straight, surface wrinkled, often more regularly than in the figure.

Isocardia ? axiniformis. Ph. Pl. V. fig. 13. Northumberland.

Cuneiform, beaks involute, surface glabrous, fine concentric striæ.

Isocardia oblonga. Sow. Pl. V. fig. 9. Kildare ; Bolland; Dublin.

Smooth ; posterior side expanded ; anterior side small, beaks curved into it.

Isocardia unioniformis. Ph. Pl. V. t. 18. Bolland.

Ovate, rather gibbous, beaks approximate incurved, surface wrinkled on the posterior slope.

Lucina ? laminata. Ph. Pl. V. fig. 12. Bolland.

Truncate oval, very depressed, surface transversely imbricated.

Venus parallela. Ph. Pl. V. fig. 8. Bolland.

Ovate, with subparallel sides ; anterior lunula deep, surface delicately furrowed.

Venus elliptica. Ph. Pl. V. fig 7. Northumberland.

Oval, depressed ; with large transverse undulations.

Cypricardia rhombea. Ph. Pl. V. fig. 10. Bolland ; Northumberland.

Rhomboidal, valves diagonally carinated.

Cypricardia glabrata. Ph. Pl. V. fig. 25. Bolland.

Ovato-rhomboidal, valves diagonally tumid.

Modiola squamifera. Ph. Pl. V. fig. 22. Bolland.

Surface covered with imbricated broad laminæ of growth.

Modiola lingualis. Ph. Pl. V. fig. 21. Castleton.

Remarkably elongated, with a curved oblique convexity from the beaks ; lines of growth delicate, forming furrows on the convexity.

Modiola elongata. Ph. Pl. V. fig. 24. Bolland.

Elongate, arcuate, margins subparallel, valves gibbous, subcarinated.

Modiola granulosa. Ph. Pl. V. fig. 23. Northumberland; Bolland.

Very elongated, depressed, surface granulose.

CUCULLÆA obtusa. Ph. Pl. V. fig. 19. Bolland.

Twice as wide as long, gibbous, oval, front inflexed; surface undulated; reticulated in the posterior slope near the hinge.

Cucullæa arguta. Ph. Pl. V. fig. 20. Bolland.

Ovato-rhomboidal, posteriorly angulate; neat furrows parallel to the margin. (The figure is partly *restored* at the extremities.)

NUCULA cuneata. Ph. Pl. V. fig. 14. Bolland.

Ovato-cuneiform, beaks near one end; radiating striæ and concentric undulations.

Nucula tumida. Ph. Pl. V. fig. 15. Bolland; Bowes; Northumberland; Kulkeagh, Ireland.

Gibbose, ovate, concentrically striated; beaks tumid.

Nucula undulata. Ph. Pl. V. fig. 16. Bolland.

Transversely ovate, depressed; with delicate concentric striæ; a ridge on the posterior slope.

Nucula claviformis? Sow. Pl. V. fig. 17. Harelaw, and Otterburn, Northumberland; Bolland.

Subconical, anterior side extended. Surface delicately striated across. Mr. Sowerby says N. claviformis is truncated at the end. I have lately seen the end of my species, it is rounded, but nearly brought to a point.

Nucula brevirostris. Ph. Pl. V. fig. 11 a. Harelaw, Northumberland.

Ovate, anterior side attenuated, obtuse; surface neatly striated across.

Nucula luciniformis. Ph. Pl. V. fig. 11. Bolland.

Obliquely ovate, depressed, smooth; posterior slope ridged; posterior end truncate.

PLEURORHYNCHUS.—I propose this name for several singular fossils ranked provisionally with cardium by the late Mr. Sowerby. Their relation to existing genera is very slight and obscure.

P. hibernicus (Cardium Sow.) Pl. V. fig. 26, (reduced) Queen's County; Bolland; Mendip.

Shaped like a horse's hoof; the base, which is the truncated anterior face, rises near the hinge into a conical umbo or rostrum; radiating striæ.

P. minax. Ph. Pl. V. fig. 27. Bolland; Kildare.

Anteriorly gibbous, and rounded; posteriorly elongate; rostrum attenuated; radiating furrows equal. (The lower figure of C. aliforme S. t. 552, appears to belong to this species.)

P. elongatus. (Cardium Sow.) Pl. V. fig. 28. Bolland.

Very much elongated transversely; anterior side conical, middle of the valves gibbous, fine radiating striæ.

P. armatus. Ph. Pl. V. fig. 29. Kildare.

Anteriorly gibbous and subtruncate; posteriorly elongate; the rostrum very long and slender.

P. trigonalis. Ph. Pl. V. fig. 30, 31, 32. Bolland.

Horse-hoof shaped; posterior part less produced than in P. hibernicus. Surface striated from the beaks.

P. aliformis. Sow. I have found some difficulty in identifying this species. The lower figure of Min. Conch. t. 552, appears to be P. minax.

CONCHIFERA MESOMYONA.

PINNA inflata. Ph. Pl. VI. fig. 1. Bolland.

Conical, inflated, with longitudinal equal small furrows. The figure is reduced.

P. costata. Ph. Pl. VI. fig. 2. Moulton; Bolland; Derbyshire.

Elongated; the middle of the valves ornamented with deep longitudinal smooth furrows. The figure is reduced. This is probably the species figured by Martin under the names of Pinna flabelliformis and P. nuda.

INOCERAMUS vetustus. Sow. Pl. VI. fig. 3, 4. Castleton; Bolland; Flasby; Todmorden; Kulkeagh; Clare; Kildare.

Ovate, smooth, front round, concentrically undulated; upper valve (fig. 4) flattish, lower valve very convex (fig. 3). It probably does not belong to Inoceramus (Sow.) but to Posidonia. (Bronn.)

AVICULA cycloptera. Ph. Pl. VI. fig. 5. Bolland.

Hinge line extended, bent at the beak; front round; a few broad radiating ridges on the middle of the valves, lines of growth imbricated.

A. tessellata. Ph. Pl. VI. fig. 6. Bolland; Colsterdale.

Hinge line extended, straight; front round; about fifteen radiating ridges.

A. radiata. Ph. Pl. VI. fig. 8. Bolland.

Hinge line extended, straight; front round; ears acute; many radiating small furrows and ridges.

A. sublobata. Ph. Pl. VI. fig. 25. Castleton.

Oblique oval, a small lobe on one side; radiating narrow flat bands, and neat concentric striæ, (the upper valve not known.)

GERVILLIA lunulata. Ph. Pl. VI. fig. 12. Colsterdale; Bolland; Isle of Man; Kildare, &c.; Hawes.

Remarkably arched, posterior side steeply ridged; surface imbricato-striate. It grows very much larger.

G. squamosa. Ph. Pl. VI. fig. 9. Bolland.

Arched, posterior side ridged; surface squamoso-striate.

G. laminosa. Ph. Pl. VI. fig. 10. Bolland; Colsterdale.

Less arched than G. lunulata and with a convex rather than ridged posterior side.

G. inconspicua. Ph. Pl. VI. fig. 13. Castleton.

The chief difference between this and the preceding form is the want of the strong posterior convexity.

PECTEN hemisphericus. Ph. Pl. VI. fig. 16. Bolland.

Lower valve very convex, circular, the sides gradually changing into the ears; concentrically squamoso-striated. (It may possibly be avicula.)

P. ellipticus. Ph. Pl. VI. fig. 15. Bolland.

An oval (smooth?) depressed species, with short ears.

P. dissimilis. Flem. Pl. VI. fig. 17. (19?) Bolland; Linlithgow.

One valve concentrically and sharply striated; the other with radiating rough small ridges.

P. arenosus. Ph. Pl. VI. fig. 20. Colsterdale; Bolland; Derbyshire; Kildare; Kulkeagh, &c.

The shell a quadrant of a circle, with rather short square ears; radiating striæ very numerous, alternately larger; minutely crenulated with many sharp circular striæ.

P. anisotus. Ph. Pl. VI. fig 22.

Rather oblong, oblique, with very unequal reticulated ears; surface obscurely radiated.

P. plicatus? Sow. Pl. VI. fig. 21.

Nearly orbicular, lower valve convex, with numerous nearly smooth radiating ribs; (ears without radiating ribs?) If the last character be constant, it is not the same as Sowerby's shell.

P. stellaris. Ph. Pl. VI. fig. 18.

Shell quadrantal, with about fifteen strong smooth rounded ribs.

P. simplex. Ph. Pl. VI. fig. 27.

Lower valve tumid, with strong radiating furrows over all the surface. Upper valve, fig. 27, much flatter, with corresponding but shallower furrows.

P. interstitialis. Ph. Pl. VI. fig. 24. Hawes; Bolland.

With about sixteen narrow, sharp, rough radiating ribs,—the intervening spaces with three striæ or finer ribs. A specimen in Mr. Gilbertson's collection has stronger ribs. Near the beak the ribs are alternately larger and smaller, ears acute.

P. deornatus. Pl. VI. fig. 26.

This has scarcely distinguishable characters, yet contrasts with the others by its smooth concentric furrows.

P. fimbriatus. Ph. Pl. VI. fig. 28. Castleton.

Oblong, depressed, with small plain ears; surface radiated with obtuse ribs and furrows, all sinuoso-imbricate.

P. papyraceus. Sow. t. 354, is found near Harrogate and in Bolland.

P. granosus. Sow. Pl. VI. fig. 7. Bolland; Kildare.

Nearly orbicular, oblique; lower valve convex, upper (fig. 7) nearly flat, radiating ribs numerous, alternately larger and smaller, imbricated; ears reticulated.

BRACHIOPODA.

Producta.—Until the structure of the shells of brachiopodous mollusca is better known, it appears prudent to retain the nomenclature of the late Mr. Sowerby. This genus belongs to the silurian, carboniferous, and new red sandstone systems.

Division A. Radiating sulci or striæ predominant.

P. Martini. Sow. Pl. VII. fig. 1, and Pl. VIII. fig. 19. Bolland; Kirby Lonsdale; High-Green-wood; Hudswell; Harrogate; Northumberland; Castleton.

Globose near the beak, widening to the produced front; radiations thread-like, flexuous.

P. costata. Sow. (et sulcata Sow.) Ph. Pl. VII. fig. 2. Bolland; Hawes; East Witton; Richmond.

Dorsally planato-concave; ribs strong, at intervals spinose, reticulated near the beak; long curved spines on the ears.

P. antiquata. Sow. Pl. VII. fig. 3. Bolland; Coverdale; Northumberland; Cumberland; Derbyshire; Flintshire; Kildare.

Old specimens quadrato-hemispherical; front produced; sides subparallel; mesial hollow wide; radiating ribs round, reticulated in all the rostral portion by concentric undulations, which are larger, fewer and spinose toward the ears. Young, plano-convex; their whole surface reticulate. *Var.* with finer sharp striæ. High-Green-wood and Kirby Lonsdale.

P. comoïdes. Sow. Pl. VII. fig. 4. Conishead; Bolland; Greenhow hill.

Globose near the beak, ears wrinkled, surface covered with *fine* undulating striæ.

P. Edelburgensis. Ph. Pl. VII. fig. 5. Addleburgh; Bolland; Fountains fell.

Semicircular, hinge line very wide, beak not prominent, deep valve evenly convex; ears flattened; both valves coarsely striated; striæ often duplicate; spines few or none. Differs from P. latissima in flattened ears.

P. latissima. Sow. Pl. VIII. fig. 1. Fountains fell; Kirby Lonsdale; Otterburn, Northumberland.

Fusiform, or convoluted; ears conical; striæ coarse; *many small bristly spines.*

P. aurita. Ph. VII. fig. 6, 7. Ulverston.

Hemispherical, ears prominent, rugose; radiating striæ obtuse; spines few. Ears rounded in old, angular in young specimens. (I suppose this to be P. hemispherica Sow. but the confusion in geological works with respect to that and P. Scotica induces me to propose this name.)

3 α var. β meniscialis. Ph. Kendal; Queen's County.

Transversely elliptical, concavo-convex, no mesial hollow; surface radiated with coarse round small ribs, and concentrically undulated near the beak.

P. quincuncialis. Ph. Pl. VII fig. 8. Bolland.

Cardinal angles right, no furrow on the deep valve; surface ridged with regular strong ribs, rising alternately into oblong tubercles.

P. scabricula. Sow. Pl. VIII. fig. 2, and VIII. 20? Bristol; Coalbrookdale; Bowes; Harelaw.

Mesial furrow broad; numerous irregular sharp spines (or oblong tubercles) in quincunx, connected in lines by slight ridges from the beak of the lower valve. (Perhaps the large specimen figured Pl. VIII. fig. 20, may be distinct; it is from Bolland.)

P. muricata. Ph. Pl. VIII. fig. 3. Harelaw; Kirby Lonsdale.

Back flattened; radiating ridges rounded, continuous, strong, muricated.

P. concinna. Sow. Pl. VII. fig. 9. Richmond; Bolland; Derbyshire.

Semicylindrical, concave along the middle, neatly striated and spinous; lesser valve flat, deeply inserted.

P. lobata. Sow. Pl. VIII. fig. 7. Arran; Otterburn, and Harelaw, Northumberland.

Distinguishable from the preceding and following, chiefly by its deeper dorsal furrow, and coarser striæ. Its spines are not noticed by Sowerby.

P. setosa. Ph. Pl. VIII. fig. 9, 17. Northumberland; Rokeby.

The length of the ears causes this to differ from P. spinosa S. to which it is otherwise similar. The front is often produced into a ridge.

P. plicatilis. Sow. Pl. VIII. fig. 4. Castleton.

Transversely elliptical; a dorsal furrow; radiating striæ, neatly decussated by many concentric undulations in the rostral half of the surface.

P. depressa. Sow. Pl. VIII. fig. 18. Florence Court.

Valves depressed; deeper one concentrically angulated; radiating striæ smooth, crossed by flexuous rounded undulations on the flat surface. I can not distinguish this from the Dudley species.

P. analoga. Ph. Pl. VII. fig. 10. Bolland; Redesdale in Northumberland.

Perhaps this is really different from the last, but it is difficult to fix on characters. The concentric undulations are less even and flexuous, the striæ less equal; the whole less neat.

P. pugilis. Ph. Pl. VIII. fig. 6. Kirby Lonsdale.

Auricles acute, spinous; radiating striæ equal, a few strong spines toward the margin.

P. gigantea. Sow. Pl. VIII. fig. 5 (reduced). Aldstone moor; Hawes; Askrigg; Dentdale; Rokeby, &c.

Oblate, very gibbous, ears rounded; broad irregular radiating undulations, covered by variously bent striæ. It grows to nine inches diameter.

P. margaritacea. Ph. Pl. VIII. fig. 8. Florence Court.

Shell very thin, gibbous in the middle, radiating striæ rounded, smooth; two or three auricular and lateral spines.

P. pectinoides. Ph. Pl. VII. fig. 11. Bolland.

Orbicular, radiating smooth ribs, duplicate towards the margin.

P. mesoloba. Ph. Pl. VII. fig. 12, 13. Bolland; Derbyshire.

Gibbous, ears obtuse-angled; surface smooth or slightly wrinkled across, with or without a few scattered spines; a mesial ridge on the convex valve and a corresponding furrow on the other.

Division B. Spines arranged on transverse undulations.

P. punctata. Sow. Pl. VIII. fig. 10. Bolland; Settle; Cumberland; Otterburn.

Oblate, hinge line abbreviated; furrow deep; concentric sulci and ridges, the ridges spinulose on the deep valve.

P. fimbriata. Sow. Pl. VIII. fig. 11, 12 (13? 16?). Bolland; Greenhow hill; Moulton; Isle of Man.

Oblong, mesial furrow slight or none; transverse sulci few, the intermediate broad ridges spinose on the rostral edge. The following may be distinct species. Var. β, laxispina, fig. 13; γ, lirata, fig. 16.

P. ovalis. Ph. Pl. VIII. fig. 14. Bolland.

Oblong, dorsal furrow slight, with faint concentric sulci, and numerous spinulose puncta.

P. granulosa. Ph. Pl. VIII. fig. 15. Bolland.

Oblate, ears rounded, no dorsal furrow, surface rough with numerous oblong spinulose puncta.

P. spinulosa. Sow. Pl. VII. fig. 14. Bolland; Wolsingham.

Semicircular, no mesial furrow, spines few.

P. pustulosa. Ph. Pl. VII. fig. 15. Bolland; Florence Court.

Rotundato-quadrate, gibbous, ears angular, furrowed, spineless; transverse undulated wrinkles, bearing numerous scattered spines, which become more and more adpressed toward the margin.

P. rugata. Ph. Pl. VII. fig. 16. Bolland.

Orbicular, wrinkled across; with scattered spines.

SPIRIFERA.—In the following species the beak is imperforate; the upper valve is convex: the hinge line generally straight.

A. Cuspidatæ. Beaks of the valves separated by a wide triangular area, the lower one not incurved. Hinge line equal to the breadth of the shell.

S. cuspidata. Sow. Pl. IX. fig. 1, 4. Bolland; Settle; Derbyshire; Kildare County; Queen's County, Ireland, &c.

Cardinal area very large; front deeply waved; sides with radiating smooth sulci; mesial fold commonly smooth. Figure 4, represents a remarkable variety, between which and fig. 1, are insensible gradations.

S. insculpta. Ph. Pl. IX. fig. 2, 3. Bolland; Derbyshire.

Cardinal area large; the mesial and two or three lateral folds very bold, acute, and strongly striated across.

S. senilis. Ph. Pl. IX. fig. 5. Bolland.

Cardinal area large, transversely striated; mesial fold indistinct; surface radiatingly striated; aspect more or less irregular.

S. crenistria. Ph. Pl. IX. fig. 6. Bolland.

Surface of the valves radiated with strong divaricating striæ crenulated by the lines of growth.

S. septosa. Ph. Pl. XI. fig. 7. Ribblehead; Burton fell; Cumberland (Mr. Salmond.)

Upper valve more convex; both radiated with very wide deep furrows, and intervening ribs, dividing into two, three, or four lesser ones towards the margin. The

septa in the lower valve divide it into three parts as in pentamerus, to which *by this insufficient character* it would be referred. Many spiriferæ exhibit, less distinctly, the same phenomenon.

S. distans. Sow. not figured. Bolland; Dublin.

Resembles Sp. semicircularis, (fig. 15,) in shape, but its mesial fold is not sulcated on the upper valve, (in some of my specimens it is not sulcated on either valve.) The cardinal area is wider than even the variety α. of S. semicircularis, (fig. 15.) It is more gibbous than that shell and has a wider frontal wave.

B. *Angustatæ. Cardinal line as wide as the shell; valves with incurved beaks. Mesial fold defined between two deeper furrows on the upper valve.*

S. semicircularis. Ph. Pl. IX. fig. (15, 16.) Chipping; Whitewell; Queen's County, Ireland; Isle of Man.

Cardinal area variable; upper valve very nearly semicircular; surface covered by radiating smooth sulci and ribs which are entire or divaricate near their origin; mesial fold sulcated. α. Cardinal angles right. β. Cardinal angles acute. (Differs from Sp. distans by the sulcated mesial fold, and is more depressed.)

S. striata. Sow. t. 270. Bolland; Derbyshire; Ireland.

It is difficult to distinguish this species from Sp. semicircularis and its congeners. The cardinal extremities are rounded or obtusely angulated; the cardinal area is concave with subparallel sides; the radiating ribs are small and often divided; the upper valve projects from the circular curve in the middle.

S. convoluta. Ph. Pl. IX. fig. 7. Bolland.

Width four times the length; cardinal area concave; surface obtusely and unequally radiated.

S. rhomboidea. Ph. Pl. IX. fig. 8, 9. Bolland; Ireland.

Width fully double the length, extremities subcylindrical; cardinal area very wide, mesial fold defined; surface radiated with obtuse smooth sulci. The great proportionate width of the cardinal area is a strong character, yet it very much resembles both Sp. convoluta, Ph. and Sp. attenuata, S. In figure it agrees with Sp. triangularis, Sow. t. 562, but the ribs of that species are bolder, and its mesial fold is different.

S. fusiformis. J. De C. Sow. Pl. IX. fig. 10, 11. Bolland.

Mesial fold indefined; surface finely radiated, cardinal area large, hollow. (The name is given by Mr. J. De C. Sowerby.)

S. triangularis. Sow. Pl. IX. fig. 12. Bolland; Kirby Lonsdale; Derbyshire.

The triangular upper valve, narrow mesial fold, and few lateral radii, agree better with Sp. triangularis than trigonalis of Sowerby.

S. trigonalis. Sow. t. 265. Kirby Lonsdale; Arran; Derbyshire; Northumberland.

Differs from the last by having (when full grown) more lateral ribs, (about twenty-four in all), sharply striated across; and a less distance between the beaks.

S. octoplicata. Sow. t. 562. Kirby Lonsdale; Pateley bridge; Derbyshire.

My specimens are not good. Its few strong plaits distinguish it from Sp. triangularis.

S. attenuata. Sow. Pl. IX. fig. 13. Bolland; Queen's County.

Width about double the length; cardinal area narrow, sulcate; cardinal extremities elongate; surface radiated with *numerous* smooth obtuse ribs.—Beaks approximate. (β. In a beautiful specimen from Kildare County, given me by Dr. Hutton of Dublin, the sides run out into long spines. It is probably a distinct species.)

S. bisulcata. Sow. Pl. IX. fig. 14. Bolland; Queen's County; Coalbrookdale, Northumberland.

Differs from the last almost only in the proportion of length to breadth, and in having fewer radiations. The furrows which bound the mesial fold on the upper valve are scarcely more prominent in this than in several others. Some of the Coalbrookdale specimens are quite as long as wide.

S. rotundata. Sow. Pl. IX. fig. 17. Bolland; Queen's County; Kildare.

Cardinal area narrower than in any of the preceding: beaks approximate, radiated with very obtuse or obscure sulci; mesial fold broad, nearly smooth. The Irish and Yorkshire specimens agree perfectly: the cardinal extremities are seldom so angular as in figure 17, from Mr. Gilbertson's collection.

S. pinguis. Sow. Pl. IX. fig. 18, 19. Bolland; Castleton.

In the greater distinctness of the lateral radii it differs from the preceding, but it may, very possibly, be only the young of that.

S. humerosa. Ph. Pl. XI. fig. 8. Greenhow hill.

Lower valve extremely large, swollen near the beaks, and *produced* in a mesial furrow, receiving the angular ridge of the upper valve: radiating ribs small, duplicate.

C. *Radiatæ*; *cardinal area not so wide as the shell; surface radiated.*

S. duplicicosta. Ph. Pl. X. fig. 1. Bolland; Derbyshire; Northumland.

Mesial fold angular; radiating ribs numerous, duplicate toward the margin.

S. integricosta. Ph. Pl. X. fig. 2. Bolland; Northumberland.

Beaks very approximate; radiating ribs very obtuse, entire.

S. planata. Ph. Pl. X. fig. 3. Bolland.

Upper valve nearly plane; radiations many, obtuse.

S. ovalis. Ph. Pl. X. fig. 5. Bolland.

Mesial fold obtusely rounded; lateral plaits broad.

S. trisulcosa. Ph. Pl. X. fig. 6. Bolland.

Smooth, oblong; one mesial and two lateral ridges on the upper valve.

S. triradialis. Ph. Pl. X. fig. 7. Bolland.

Smooth, orbicular; one mesial and two lateral ridges on the upper valve, which is flattened. (Analogous to Sp. planata.)

S. sexradialis. Ph. Pl. X. fig. 8. Bolland.

Oblong, one mesial and six lateral ridges on the upper valve.

S. linguifera. Ph. Pl. X. fig. 4. Bolland.

Oblong, convex, without angles; mesial fold rounded, prominent; lateral radiations obscure.

D. *Glabratæ. Cardinal area not so wide as the shell; surface not radiated.*

S. decora. Ph. Pl. X. fig. 9. Bolland.

Nearly orbicular, convex, beak prominent; faintly radiated; mesial fold indistinct, partially divided.

S. glabra. Mart. Sow. Pl. X. fig. 10, 11, 12. Bolland; Arran; Ireland; Isle of Man.

A variable species. Smooth; length from $\frac{1}{2}$ to $\frac{2}{3}$ of the width: gibbous, rounded; the mesial fold very large and prominent, round or flattened in the middle; lateral radiations obscure or none. (I unite Sp. glabra and Sp. obtusa of Sowerby.)

S. symmetrica. Ph. Pl. X. fig. 13. Bolland.

Rotundato-quadrate, gibbous, smooth; mesial fold wide, (sometimes divided in the middle.)

S. mesoloba. Ph. Pl. X. fig. 14. Bolland.

Depressed, surface imbricate, mesial fold distinct.

S. lineata. Mart. Sow. Pl. X. fig. 17. Kirby Lonsdale; Crooklands; Northumberland.

Surface imbricate; no mesial fold; convex.

S. elliptica. Ph. Pl. X. fig. 16. Bolland; Queen's County, Ireland.

Mesial fold obtuse; surface radiated, and concentrically striated. (The concentric striæ vanish with age.)

S. imbricata. Sow. Ph. Pl. X. fig. 20. Bolland; Derbyshire; Northumberland.

Transversely elliptical, mesial fold indistinct or none; surface with strong radiating striæ, interrupted by concentric imbricating laminæ.

E. *Terebratuliformes. Cardinal area none.*

S. fimbriata. Ph. Florence Court.

Orbicular, depressed, beak of the lower valve prominent, but small; surface strongly radiated and concentrically imbricated.

S. planosulcata. Ph. Pl. X. fig. 15. Bolland; Queen's County.

Pentahedral, depressed, middle of each valve planosulcate.

S. expansa. Ph. Pl. X. fig. 18. Bolland.

No mesial fold; depressed, concentrically striated, with fine radiations.

S. glabristria. Ph. Pl. X. fig. 19. Bolland.

Mesial fold prominent; depressed; fine radiating striæ (the latter character varies).

S. squamosa. Ph. Pl. X. fig. 21. Kendal; Florence Court.

Depressed; mesial ridge small; transversely imbricated; smooth.

S. globularis. Ph. Pl. X. fig. 22. Bolland.

Subglobose; smooth; mesial fold broad.

S. elongata. Ph. Pl. XI. fig. 9. Bolland.

Pentahedral, smooth, with obtuse radiations.

F. *Filosæ. Surface with prominent radiating threads.*

S. resupinata. Mart. Sow. Pl. XI. fig. 1. Bolland; Greenhow hill; Hawes; Otterburn; &c.; Derbyshire.

Transversely elliptical; lower valve undulato-concave; upper valve flattened in the middle. Surface finely radiated with striæ which rise at intervals to prominent spinous lines.

S. connivens. Ph. Pl. XI. fig. 2. Bolland.

Subglobose, margin undulated; radiating striæ rather coarse.

S. filiaria. Ph. Pl. XI. fig. 3. Bolland; Fountains' fell; Derbyshire; Otterburn.

Very depressed, elongate; hinge line abbreviated, radiating striæ fine.

S. arachnoïdea. Ph. Pl. XI. fig. 4. Stradone; Haltwhistle; Allenheads; near Hesket-Newmarket.

Very depressed, truncato-orbicular. Hinge line wide as the shell; striæ fine, sharp, and continually subdivided; upper valve convex as in S. resupinata.

S. radialis. Ph. Pl. XI. fig. 5. Florence Court; Cumberland.

Very wide, semielliptical, hinge straight, front circular; strong radiating ridges, and intervening smaller ones, crossed by imbricated lamellæ.

S. papilionacea. Ph. Pl. XI. fig. 6. Bolland; Otterburn.

Extremely wide, semielliptical, with very fine rather bent radiating striæ; in young specimens the striæ are beautifully crenulated.

ORBICULA nitida. Ph. Pl. XI. fig. 10, 11, 12, 13. Bowes; Pateley bridge; Lee, Harelaw, and Otterburn; Coalbrookdale.

Oval, glabrous, finely radiated; lower valve flat, upper conico-lenticular, apex near the narrower end. The Coalbrookdale specimens are slightly more depressed than those of Yorkshire and Northumberland.

LINGULA squamiformis. Ph. Pl. XI. fig. 14. Bolland.

Oblong with parallel sides; truncate in front, acuminated retrally; a central oblong depression; surface with finely radiating and concentric lines. It does not quite agree with L. mytilloides of Sowerby.

L. elliptica. Ph. Pl. XI. fig. 15. Ashford in Derbyshire.

Long elliptical, acuminated retrally; surface with delicate radiating and concentric lines.

L. marginata. Ph. Pl. XI. fig. 16. Bowes.

Very oblong, with parallel sides, truncate in front, rounded retrally, edge of the valves turned up; slight mesial ridge on a flat space; small oval hollow, fine radiating and concentric lines.

L. parallela. Ph. Pl. XI. fig. 17—19. Northumberland.

Magnified views of a species which seems different from the last, by its rounded front, and equally convex surface. 19, flatter valve, 17, 18, deeper valve.

TEREBRATULA. Div. 1.—*Smooth, generally oblong; the middle of the front even or depressed.*

T. hastata. Sow. Pl. XII. fig. 1. Derbyshire; Otterburn; Bolland; Queen's County.

Depressed, valves plane or plano-sulcate in the middle, with (irregular) radiating striæ. Outline variable, from pentagonal to ovato-trigonal.

T. sacculus. Mart. Sow. Pl. XII. fig. 2. Bolland; Greenhow hill; Kirby Lonsdale; Orton; Northumberland.

Gibbous, valves sulcate, or plano-sulcate in the middle; front emarginate, obtuse.

T. pentaëdra. Ph. Pl. XII. fig. 3. Bolland; Orton.

Pentagonal, depressed, surface undulated, front and sides emarginate, perforation of the beak minute.

T. ambigua. Ph. (Spirifera Sow.) Pl. XI. fig. 21. Northumberland.

Pentagonal, front deeply undulated, beak with a large round aperture.

T. rhomboidea. Ph. Pl. XII. fig. 18, 19, 20. Bolland.

No lateral plaits; perforation minute.

T. seminula. Ph. Pl. XII. fig. 21, 22, 23. Bolland.

One lateral plait; perforation minute.

Div. 2.—*Plaited; generally oblate; the middle of the front even or elevated.*

T. acuminata. Mart. Sow. Pl. XII. 4—9. Bolland; Queen's County; Kildare.

The varieties are almost innumerable, and a specific character is at present impossible. (T. acuminata et T. platyloba Sow.)

Var. 1. *Front angular.* α. No mesial plaits; with or without lateral plaits, fig. 4; Young, fig. 5.

β. Mesial plaits variable; with or without lateral plaits.

γ. Whole surface sharply plaited.

2. *Front arched.* With mesial plaits fig. 7.

Young of the same fig. 8, 9, 6.

T. mesogona. Ph. Pl. XII. fig. 10, 11, 12. Bolland.

Tetrahedral, frontal elevation single or bifid; sides one or two-plaited. It is a miniature copy of the first *var.* of T. acuminata.

T. reniformis. Sow. Pl. XII. fig. 13, 14, 15. Bolland; Queen's County.

Reniform; sides without plaits, inflated; mesial fold extremely wide. α. No mesial ridge, β. three to five obtuse mesial ridges, γ. three to five acute mesial ridges.

T. pugnus. Mart. Sow. Pl. XII. fig. 17.

Oblato-deltoidal; all the plaits short, rather obtuse; surface striated.

T. sulcirostris. Ph. Pl. XII. fig. 31, 32. Bolland.

Rhomboideo-deltoidal, edge sharp, plaits obtuse; mesial plaits five to nine; upper valve sulcate toward the beak. α. plaits numerous. β. plaits fewer.

T. flexistria. Ph. Pl. XII. fig. 33, 34. Bolland.

Oblate, depressed, mesial elevation rounded; lower valve smaller, flatter, with inconspicuous beak; many obtuse striæ, *much curved on the sides.*

T. tumida. Ph. Pl. XII. fig. 35. Bolland.

Oblate, tumid, lower valve flatter, with inconspicuous beak; striæ strong and rounded on the middle, smaller and *curved on the sides.*

T. pleurodon. Ph. Pl. XII. α. fig. 25, 26, 28. β. 16, 29, 30. γ. 27. Bolland; Kirby Lonsdale; Orton.

Transversely ovate, beak prominent, ribs sharp, extending to the beak; *sides very deeply reflexo-dentate.* α. mesial elevation considerable sides, much reflexed, *ribs very acute.* β. (raricosta), plaits few; 16. a gigantic specimen; 29, 30 young. γ. (polyo-

donta,) mesial ribs numerous; margin squared. I have a very singular variety from Kirby Lonsdale with much elevated biplicate mesial fold, and projecting quadriplicate sides. (avicularia.)

T. ventilabrum? Ph. Pl. XII. fig. 36, 38, 39. Bolland, &c.

Whether this be distinct from T. sulcirotris, I am not sure. It resembles an oolitic species. α. no mesial elevation, fig. 36. β. ribs rounded and vanishing toward the margin.

T. excavata. Ph. Pl. XII. fig. 24. Isle of Man.

Oblong, flattened, with steep edges, *excavated on the sides near the beak*, plaits very deep and angular. α. mesial plaits three; lateral two; β. mesial plaits four.

T. radialis. Ph. Pl. XII. fig. 40, 41. Bolland.

Orbicular, no mesial fold; ridges equal, rounded, radiating.

T. proava. Ph. Pl. XII. fig. 37. Bolland.

Oblong, beak produced, radiations obtuse, mesial fold square. Strongly allied to the oolitic species T. obsoleta, T. socialis, &c.

T. antiquata. Ph. Pl. XI. fig. 20. Bolland.

A very singular small brachiopodous shell (perhaps producta) of an oval figure; lower valve convex, upper plane with two diverging convexities, hinge line straight.

GASTEROPODA.

PATELLA scutiformis. Ph. Pl. XIV. fig. 1. Bolland.

Depressed, scutiform, elliptical, smooth, vertex acute, inflexed, nearly marginal; very fine radiating striæ.

P. sinuosa. Ph. Pl. XIV. fig. 2. Bolland.

Depressed, smooth, sinuoso-oval; vertex irregular, prominent, near to the narrow end.

P. mucronata. Ph. Pl. XIV. fig. 3. Bolland.

Conical, smooth, depressed; apex mucronate, acute, central; limb orbicular, base not plane.

P. curvata. Ph. XIV. fig. 4. Bolland.

Curvato-conical, smooth; base plane; limb orbicular; apex acute, central.

P. retrorsa. Ph. Pl. XIV. fig. 5. Bolland.

Depressed-conical, with many broad radiating sulci; limb elliptical, undulated; apex acute, retroflexed.

P. lateralis. Ph. Pl. XIV. fig. 6. Bolland.

Conical, smooth, a lateral sulcus, and posterior radiations; apex acute.

METOPTOMA.—New genus. Patelliform, face under the apex truncate.

M. pileus. Ph. Pl. XIV. fig. 7. Bolland.

Conical, smooth.

M. imbricata. Ph. Pl. XIV. fig. 8. Bolland.

Conical, concentrically ribbed.

M. elliptica. Ph. Pl. XIV. fig. 9. Bolland.

Convex, vertex terminal.

M. oblonga. Ph. Pl. XIV. fig. 10. Bolland.

Oblong, convexo-conical; limb rounded, expanded in front.

M. sulcata. Ph. Pl. XIV. fig. 11. Bolland.

Convex, concentrically sulcate.

PILEOPSIS? trilobus. Ph. Pl. XIV. fig. 12, 13. Bolland.

Subconical, arched, narrowed toward the incurved free apex; aperture trilobate.

P. tubifer. Sow. Pl. XIV. fig. 14. Bolland.

Narrow, arched; three rows of spines; (the middle one obscure.)

P. striatus. Ph. Pl. XIV. fig. 15. Bolland; Kildare County; Northumberland.

Oval, arched toward the incurved free apex; sharp radiating striæ.

P. neritoides. Ph. Pl. XIV. fig. 16, 17, 18. Bolland.

Obliquely spiral; spire flattened; lines of growth strong, irregular; aperture oval; concentric striæ on the base.

P. vetustus.? Sow. Pl. XIV. fig. 19. Bolland.

Subconical, irregular, apex spiral; surface with spiral folds; aperture round?

P. angustus. Ph. Pl. XIV. fig. 20. Bolland.

Spiral, apparently smooth, narrow; aperture expanded.

NATICA ampliata. Ph. Pl. XIV. fig. 21, 24a. Bolland; Northumberland.

Hemispherical, spire of two inconspicuous volutions; lip expanded, columella plane; striæ equal, filiform.

N. lirata. Ph. Pl. XIV. fig. 22. Bolland.

α. oval, spire mammillary, of two or three volutions, crossed by equidistant laminæ; β. spiral interlaminar striæ. The shell is smooth within.

N. elliptica. Ph. Pl. XIV. fig. 23. Bolland; Northumberland.

Depressed, elliptical, spire short; striæ oblique, fine; columella arched, plane.

N. planispira. Ph. Pl. XIV. fig. 24. Bolland.

Columella callous above, top of the volutions planate, plicistriate.

N. variata. Ph. Pl. XIV. fig. 26, 27. Bolland.

Oval, depressed, apex acute; striæ partly oblique and partly spiral.

N. plicistria. Ph. Pl. XIV. fig. 25. Bolland; Kirby Lonsdale; Bristol; Northumberland; Kildare.

Oval, depressed, columella not callous; spire of three volutions plicistriate above. α. volutions flattened above, with age concave. β. volutions not flattened above.

N. elongata. Ph. Pl. XIV. fig. 28. Bolland.

Elongate oval, apex mammillary; striæ oblique, minute.

N. tabulata. Ph. Pl. XIV. fig. 29. Bolland.

Ovate, finely striated; volutions tabular in the upper part.

Euomphalus. Gen. Char. Discoid; dextrally spiral; upper disk plane, lower concave; cavity chambered; septa imperforate.

E. pentangulatus. Sow. t. 45. fig. 1, 2. Ph. Pl. XIII. fig. 13. Bolland; Dublin; Kildare.

Whorls carinated above, obtusely angulated, or rounded below; lines of growth fine. Fig. 13 is a section to shew the chambered structure. From the mouth a certain distance inwards the last chamber is seen filled with stony matter; beyond this, a second space is occupied with brown sparry substance; and from this to the inner chambers is clearer spar; the chambers are full ot spar with here and there a cavity, as in ammonites.

E. catillus. Martin, Ph. XIII. fig. 1, 2. Buxton; Tideswell; Winster; Bolland.

Each side of the whorls carinated. 1, the lower; 2, the upper side.

E. calyx. Ph. Pl. XIII. fig. 3. Bolland.

Beneath wider than above, excavated; the margin carinated. The figure shews the lower side.

E. bifrons. Ph. Pl. XIII. fig. 4. Bolland.

Whorls carinato-tuberculated above, obtusely angulated or rounded below. (This is not Euomph. nodosus Sow. which is tubercled on the under side.)

E. pugilis. Ph. Bolland.

Whorls tuberculated on both sides. This distinguishes it from E. bifrons.

E. cristatus. Ph. Pl. XIII. fig. 5. Bolland.

Whorls round, widely disjoined; a large double dentated dorsal crest, continued to the inner whorls.

Cirrus acutus. Sow. Pl. XIII. fig. 12. Bolland; Derbyshire.

Acutely conical, apex mammillary, volutions round, plane above, striated across.

C. tabulatus. Ph. Pl. XIII. fig. 7. Bolland; Northumberland; Kendal.

Depresso-conical, volutions subquadrate, above tabulate or concave, aperture oval, transverse.

C. pentagonalis. Ph. Pl. XIII. fig. 8. Bolland.

Conical, obtuse, volutions subpentagonal, margin of the umbilicus acute, aperture oval, transverse.

C. rotundatus. Sow. Pl. XIII. fig. 15. Bolland; Kirby Lonsdale; Northumberland.

Obtusely conical, volutions rounded.

C. pileopsideus. Ph. Pl. XIII. fig. 6. Bolland.

Very depressed, irregularly striated.

C. spiralis. Ph. Pl. XIII. fig. 14. Bolland.

Obtusely conical, volutions rounded, oblique and spiral striæ.

TURBO tiara. Sow. Ph. Pl. XIII. fig. 9. Bolland.

Conical; whorls convex beneath, flattened on the sides, crowned on the upper part by very prominent elongated round ribs.

T. semisulcatus. Ph. Pl. XIII. fig. 10. Bolland.

Ovato-conical; whorls smooth below, longitudinally furrowed above.

T. biserialis. Ph. Pl. XIII. fig. 11. Bolland.

Ovato-conical, whorls bearing elongated tubercles alternating in two rows.

PLEUROTOMARIA. A considerable proportion of the following species certainly belongs to this genus. The others are at least allied to it. Mr. Sowerby's Helix carinata M. C. t. 10, and Helix striata M. C. t. 171, belong to this genus. The specimen from which the figure in Min. Conch. t. 10, was drawn is copied in Pl. XV. fig. 1.

P. flammigera. Ph. Pl. XV. fig. 2. Bolland.

Surface universally decussated with spiral and longitudinal striæ; band broad, depressed, with arched striæ; colour varied with zigzag flashes.

P. tumida. Ph. Pl. XV. fig. 3. Bolland.

Spire obtuse, whorls few, tumid, excavated above, band broad, depressed, with arched striæ; spiral striæ indistinct.

P. expansa. Ph. Pl. XV. fig. 4. Bolland.

Depressed-conical, whorls few; band depressed, with arched striæ; surface with oblique striæ, and traces of spiral lines.

P. sulcatula. Ph. Pl. XV. fig. 5. Bolland; Isle of Man, &c.

Depressed, conoidal, whorls few, convex, above spirally furrowed, beneath striated; band narrow.

P. sulcata. Ph. Pl. XV. fig. 6. Bolland.

Ovoid, spire acute; whorls few, rounded, with rounded spiral sulci; band obscure.

P. depressa. Ph. Pl. V. fig. 7. Bolland.

Depressed; whorls plane above, convex and concentrically striated beneath; band prominent.

P. inconspicua. Ph. Pl. XV. fig. 8. Bolland.

Depressed; whorls few, convex, band very faintly marked and narrow, longitudinal striæ distinct, undulated; aperture transversely oval.

P. strialis. Ph. Pl. XV. fig. 9. Bolland.

Shaped as the last, but the spire more acute; band broad, plain; surface spirally striated.

P. interstrialis. Ph. Pl. XV. fig. 10. Bolland.

Aperture nearly round; base convex, spirally striated; spire conical, acute; body whorl tricarinate, two or three striæ between the keels; longitudinal fimbriated striæ.

P. atomaria. Ph. Pl. XV. fig. 11. Bolland.

Base convex, spire tabulated, two spiral sharp carinæ; surface reticulato-striated; striæ punctulated.

P. sculpta. Ph. Pl. XV. fig. 12. Bolland.

Spire acute, tabulated; whorls tricarinate; the intercarinal spaces lightly striated; the upper and lower surfaces longitudinally plaited.

P. lirata. Ph. Pl. XV. fig. 13. Bolland.

Spire acute, conical; band prominent, with arched striæ; upper surface obliquely, lower directly plaited.

P. undulata. Ph. Pl. XV. fig. 14. Bolland.

Ovate, spire small, acute; whorls convex; band broad; with longitudinal undulated striæ, every third larger than the others.

P. abdita. Ph. Pl. XV. fig. 15. Bolland.

Depressed; whorls rounded, with a *subsutural band*, (hence its name.)

P. fusiformis. Ph. Pl. XV. fig. 16. Bolland.

Fusiform; whorls tricarinate: the lower carina sutural.

P. squamula. Ph. Pl. XV. fig. 17. Bolland.

Conical, whorls obliquely costulated: costulæ squamous, entire, or divided, or alternately long and short.

P. monilifera. Ph. Pl. XV. fig. 10, a. Bolland.

Whorls bicarinate; spiral moniliform striæ.

P. limbata. Ph. Pl. XV. fig. 18. Bolland.

Depresso-conical, whorls costulated as in P. squamula, but nodular on the upper and lower edges.

P. gemmulifera. Ph. Pl. XV. fig. 19. Bolland.

Depresso-conical, whorls convex above, flat beneath; edge nodular; spiral striæ, gemmuliferous above.

P. excavata. Ph. Pl. XV. fig. 20. Bolland.

Conical, whorls carinated at the angle, nearly plane above and below, umbilicus closed.

P. acuta. Ph. Pl. XV. fig. 21. Bolland.

Whorls tumid, sharply carinated; oblique striæ above the keel, spiral lines below, (a reversed shell.)

P. conica. Ph. Pl. XV. fig. 22. Bolland; Derbyshire.

Conical, acute, umbilicate; band bicarinate, striæ acutely elevated and oblique above. Some varieties have three keels, a sulcus separating the two upper ones. On some specimens are spiral striæ.

P. concentrica. Ph. Pl. XV. fig. 23. Bolland.

Turrited, whorls quadrate, convex below, plane above, spirally sulcated; basal furrows largest, umbilicus closed.

P. vittata. Ph. Pl. XV. fig. 24. Bolland; Otterburn.

Turrito-conical, whorls convex, band very broad, and flat; striæ slightly oblique.

P. tornatilis. Ph. Pl. XV. fig. 25. Bolland.

Ovate, whorls convex; band very broad, a furrow on each side; spiral striæ above and below, two basal furrows.

P. helicoides. Sow. Pl. XV. fig. 26. Bolland.

Depressed, umbilicate; whorls rounded; lines of growth faint, retroflexed in the middle; aperture lunate; edge of umbilicus spirally striated.

P. ovoïdea. Ph. Pl. XV. fig. 27. Bolland; Derbyshire; Isle of Man; Otterburn in Northumberland.

Ovate, whorls subangulate below, lines of growth flexuous.

P. glabrata. Ph. Pl. XV. fig. 28. Bolland.

Lenticular, rounded, smooth.

P. biserrata. Ph. Pl. XV. fig. 29. Derbyshire.

Conical, acute; sutural edge and lower angle of the whorls carinato-dentate; between them a crenulated line; base with three furrows; oblique striæ.

P. serrilimba. Ph. Pl. XV. fig. 30. Derbyshire.

The angle of the spire more acute than in the last.

MELANIA constricta. Sow. Pl. XVI. fig. 1. Bolland; Kirby Lonsdale; Tideswell; Kildare.

Turrited, smooth; whorls tumid below, contracted above, with a crenated sutural margin.

M. sulculosa. Ph. Pl. XVI. fig. 1, a. Bolland; Kildare.

Elongated, volutions convex, with longitudinal arched sulci deepening toward the lower part of the whorls.

M. tumida. Ph. Pl. XVI. fig. 2. Bolland; Kildare.

Turrited, smooth, finely striated, volutions remarkably convex, numerous.

M. scalarioidea. Ph. Pl. XVI. fig. 3. Bolland.

Elongate, volutions broad, slightly convex, with longitudinal equal filiform elevations.

M. rugifera. Ph. Pl. XVI. fig. 26. Otterburn; &c.; Northumberland.

Elongated to a fine point; whorls convex, inferiorly concave and adpressed at the suture; on the lower half of each oblique, slightly arched, very strong ribs, prominent inferiorly. In young shells the ribs cover all the whorl.

TURRITELLA? tenuistria. Pl. XVI. fig. 4.

Imbricato-conical; whorls broad, plane, angular below, spirally and obliquely striated.

T. spiralis. Ph. Pl. XVI. fig. 5.

Obliquely conical, imbricate; whorls broad, reticulato-striate, with spiral threads, Var. with the sutural and lower edges prominent.

T. suturalis. Ph. Pl. XVI. fig. 6. Bolland; Kirby Lonsdale.

Conical, whorls broad, prominent at the sutural and lower edges, concave below the former; smooth. One specimen has the sutural and lower edges of a milk white colour.

T. tæniata. Ph. Pl. XVI. fig. 7.

Turrited, elongate; volutions broad, very convex, with a mesial flat band; striæ flexuous.

The specific differences of these turritellæ? must be regarded as provisional only, until more specimens have been compared.

T. triserialis. Ph. Pl. XVI. fig. 25, Otterburn; Northumberland.

Elongate, volutions convex, with three medial, one sutural and one inferior, spiral granulated lines.

T. acicula. Ph. Otterburn; Northumberland.

Very elongate, volutions with three medial spiral granulated lines, the upper one set on an angle.

BUCCINUM. Sow. or rather MELANOPSIS? to judge from what can be seen of the apertures.

B. parallele. Ph. Pl. XVI. fig. 8. Bolland.

Upper part of each whorl plane, and striated, the lower parts convex, with many equal spiral furrows.

B. imbricatum. Sow. Pl. XVI. fig. 9, 17, 18, 19, 20. Bolland; Isle of Man.

Ovato-lanceolate, whorls slightly convex, smooth, finely striated: striæ nearly direct.

B. acutum. Sow. Pl. XVI. fig. 11, 21. Bolland; Northumberland; Kildare.

Elongate, volutions convex, smooth; delicately striated.

B. curvilineum. Ph. Pl. XVII. fig. 13, 22, 23. Bolland.

Elongate, volutions very broad, smooth, very obliquely striated. (Young, fig. 22, marked with subsutural lines.)

B. rectilineum. Ph. Pl. XVI. fig. 10. Bolland.

Oval, tumid below, smooth, striæ direct; colour stripes flexuous. (Possibly var. of B. imbricatum.)

B. sigmilineum. Ph. Pl. XVI. fig. 12. Bolland; Kildare.

Elongate, volutions very convex: striæ sigmoidal. (Compare with B. acutum.)

B. vittatum. Ph. Pl. XVI. fig. 14. Bolland.

Elongate, volutions very convex, with one broad flat mesial band: aperture oval.

B. globulare. Ph. Pl. XVI. fig. 15. Bolland.

Subglobular, whorls very convex; inconspicuous spiral striæ.

B. ampullarioideum. Ph. Otterburn; Northumberland.

Ovato-conical, spire attenuated, very acute, the body whorl tumid, concave at the suture.

ROSTELLARIA angulata. Ph. Pl. XVI. fig. 16. Bolland.

Whorls angular, the upper ones tricarinate.

CEPHALOPODA MONOTHALAMIA.

BELLEROPHON. An extinct genus, unknown in the superior strata.

B. tangentialis. Ph. Pl. XVII. fig. 6, 7, and 14. Bolland; Queen's County.

Cylindrico-globose, with a largely rounded umbilicus; aperture greatly expanded; back broad with a sharp and narrow keel, sending off straight ridges and furrows which are perpendicular to the keel and form tangents to the inner margin.

B. costatus. Sow Pl. XVII. fig. 15. Craven; Bolland.

Subglobose, umbilicus small, rounded, dorsal band broad; striæ sharp, arched from the umbilicus to a deep V-shaped dorsal sinus. I have attempted a *restoration* of the species from a fine specimen in the Yorkshire Museum. The inner part of the shell covers with its smooth expansion the ridges of the dorsal face.

B. hiulcus. Sow. Pl. XVII. fig. 5. Bolland; Derbyshire.

Differs from the last chiefly by its finer striæ, and greater width.

B. tenuifascia. Sow. Pl. XVII. fig. 9, 10. Bolland.

Form nearly as the last; umbilicus small, striæ fine: keel narrow and sharp.

B. decussatus. Flem. Pl. XVII. fig. 13, Kulkeagh ; Linlithgowshire.

Globular, aperture very much expanded, axis solid, band tumid ; shell covered by small spiral ridges and furrows, crossed by transverse sharp threads forming scales or elevated points on the ridges.

B. apertus. Sow. Pl. XVII. fig. 4. Fermanagh ; Carlingford ; Kirby Lonsdale ; Bristol.

Nearly spherical, (without a band?) inner whorls concealed in the shell, (apparent in the cast) axis solid and very thick ; sides of the aperture expanded.

B. cornu arietis. Sow. Pl. XVII. fig. 16. Kendal ; Northumberland.

Whorls few, rapidly enlarging from a rather compressed to a very much expanded section ; aperture expanded on the sides, with a deep acute dorsal sinus. Shell very thick.

B. Urii? Flem. Pl. XVII. fig. 11, 12. Bowes ; Bolland ; Harelaw ; Linlithgowshire.?

Globular, aperture very expanded, axis solid, *no band*, smooth, many regular spiral furrows, the intermediate ridges narrow, rounded. The cast of the interior smooth. In respect of shape it seems to differ from Dr. Fleming's description.

B. spiralis. Ph. Pl. XVII. fig. 8. Bowes ; Harelaw, and Otterburn.

Ovate, umbilicate, back and edges of the umbilicus obtuse-angled. Many spiral furrows and ridges, surface very minutely granular. (Cast smooth.)

B. Woodwardii. (Nautilus Woodwardii, Sow.) Pl. XVII. fig. 1, 2, 3. Bolland ; Kulkeagh ; Derbyshire.

Lenticular, whorls few, subrhomboidal, partly involute ; *a dorsal sulcus*, and many spiral beaded lines. In old shells the lines are nearly plain striæ, and the inner whorls are more concealed.

CEPHALOPODA POLYTHALAMIA.

The following species though referred to Nautilus, a genus of existing mollusca, really belong to several genera most of them extinct.

NAUTILUS dorsalis. Ph. Pl. XVII. fig. 17 ; Pl. XVIII. fig. 1, 2.

Spire rapidly augmenting, so as to leave a large very deep umbilicus ; siphuncle dorsal ; septa distinct. There are two if not three varieties of this same general form, all with dorsal siphuncle. α. has a rounded umbilicus and inner whorls partly concealed, (Bolland.) β. has an angular umbilicus, whorls more involute, (Bolland.) γ. less involute, umbilicus open, rounded, (Kildare.)

N. endosiphonus. Ph. Coal shale of Halifax.

Aperture quadrangular, narrowing toward the flat back, lunulate on the inner side ; *siphuncle very near the inner edge.*

N. goniolobus. Ph. Pl. XVII. fig. 23. Bolland.

Subglobose, involute, umbilicus small; sutures retroflexed into a round dorsal sinus; first lateral lobe angular; second inconspicuous.

N. globatus. Sow. Pl. XVII. fig. 20, 28? Bolland.

The umbilicus appears less angular than in Min. Conch.

N. bistrialis. Ph. Pl. XVII. fig. 21. Bolland.

Two or three spiral striæ on the edge of the large umbilicus.

N. bilobatus. Sow. t. 249. Closeburn; Coalbrookdale.

Subglobose, transversely striated, umbilicus very deep; septa with one deep *forward* bend on the back; siphunculus central.

N. cyclostomus. Ph. Pl. XXII. fig. 26; Pl. XVII. fig. 29; Pl. XVIII. fig. 3. Castleton; Bolland; High-Green-wood.

Shell partly spiral, rapidly enlarging to a nearly straight cone; crossed by fine flexuous striæ; sutures concave outwardly, slightly retroflexed on the back. Aperture nearly round. Siphunculus near the outer edge. Number of spirals variable.

N. tuberculatus. Sow. Pl. XXII. fig. 27, 29. High-Green-wood; Kildare.

Discoidal, calyciform, striæ retroflexed on the broad back; edges of the umbilicus tuberculated: septa concave outwardly; siphuncle central. In young shells two lateral ridges appear.

N. multicarinatus. Sow. Cork; Cumberland.

Cylindrico-discoidal; back flattened, with many spiral ridges and furrows.

N. cariniferus. Sow. Pl. XVII. fig. 19. Kildare; Coalbrookdale; Cork; Bolland.

Globoso-discoidal, inner whorls half exposed in a large conical umbilicus, bounded by a sharp ridge; two spiral ridges and retroflexed striæ on the back. Septa concave outwardly, siphuncle nearer the outer edge.

N. ingens. Mart. Pl. XVIII. fig. 4. Coniston near Gargrave; Clattering dykes.

Discoid, inner turns a little concealed, back round, aperture orbicular, obscurely angular toward the inner edges, septa numerous, siphuncle central. Its round back is the only difference from N. pentagonus of Sowerby.

N. biangulatus. Sow. Pl. XVII. fig. 22. Ireland; Bolland.

Spheroidal with a large deep umbilicus; a keel upon each side in young specimens; aperture transversely elliptical; siphuncle central; septa very concave.

N. sulciferus. Ph. Florence Court; Enniskillen.

Spheroidal, umbilicus large, deep, bordered by a raised angle or keel, back bevelled toward the keels, and sulcated in the middle. Closely allied to the preceding species.

N. costalis. Ph. Pl. XXII. fig. 30. Queen's County; Kildare.

Spheroidal, umbilicus deep, rounded, whorls covered by transverse flutings, the interstices rising to sharp ridges on the back, and uniting obscurely into undulations on the edge of the umbilicus. Constrictions at intervals parallel to the ridges. Mouth lunate. On the shell are elevated striæ parallel to the ridges. It grows very large.

N. sulcatus. Sow. Pl. XXII. fig. 31, 32. Castleton; Kulkeagh, &c. in Fermanagh; Bowes; Northumberland; Coalbrookdale; Cumberland.

Discoid; whorls exposed, ventricose near the inner margin, with two small spiral furrows, concave on the side; two keels toward the back which is concave. Striæ fine, sigmoidal. Septa concave outwardly; siphuncle nearer the outer edge.

N. tetragonus. Ph. Pl. XXII. fig. 33, 34; Pl. XVII. fig. 24. Kulkeagh; Bolland; Northumberland.

Flat, discoidal, whorls tetragonal, back slightly concave, with a small spiral ridge within the angles; striæ bent, sharp, rising into plaits on the edges: septa concave outwardly; (oblique undulations on the sides of the cast.) Var. β. inner edge rounded.

N. subsulcatus. Ph. Pl. XVII. fig. 18, 25. Kildare; High-Greenwood; Bolland; Coalbrookdale.

Discoidal, smooth, with many sharp sigmoidal and some spiral striæ; whorls quadrangular, the back concave along the middle, bevelled to the side; the sides concave toward the outer edge, and convex toward the abrupt marginal slope, siphuncle near the outer edge, aperture oblong, (analogous to N. sulcatus.)

N. oxystomus. Ph. Pl. XXII. fig. 35, 36. Florence Court; Enniskillen; Isle of Man.

Very depressed, lenticular, smooth, back acute; inner volutions half exposed, septa concave outwards. The septa are shewn in the figure as far as they could be traced.

GONIATITES, Von Buch. An extinct genus unknown in superior strata.

G. striatus. (Amm. striatus, Sow.) Pl. XIX. fig. 1—3. Bolland; Flasby; Derbyshire, &c.

Shell very convex, umbilicate, spirally striated, (with internal strengthening transverse ridges, leaving bent constrictions on the mould); latero-dorsal lobes of the septa angular. The constrictions on the mould are extremely variable in number. Where very few the septa are closer. Figure 3, may be taken as a type of the external edge of the septa of the genus; the arrow points toward the aperture, and passes along the middle of the back. The nomenclature used in the following pages will be understood from the subjoined notation, referring to fig. 3.

D. dorsal region, L. lateral region, M. marginal or umbilical region,	included between lines; the *internal edge* of the septum is not regarded. M. is generally disregarded in description and is omitted in all the other figures.

l. lobe. *s.* sinus. *σ.* the siphuncle, which is not a continuous tube but passes retrally from the septal plate a short distance. As an example, the septum of G. striatus may be thus marked and described. Dorsal lobe (D. *l.*) bifid, dorsal sinus (D. *s.*) acute; first lateral lobe (L. *l'*.) acute, twice as long as the dorsal lobe, second lateral lobe (L. *l''*.) obtusely rounded, shorter than the first; marginal sinus (M. *s.*) angular.

G. sphæricus. (Amm. sphæricus, Sow.) Pl. XIX. fig. 4. 5, 6. Derbyshire; Bolland; Isle of Man; and Kildare County.

More globose than the preceding; shell spirally striated, with (variable) internal ridges; septa as in the preceding, except that the first lateral lobe is less acute, or even rounded; it grows twice as large. 6. From a Bolland specimen.

G. crenistria. Ph. Pl. XIX. fig. 7, 8, 9. Bolland; Queen's County; Fermanagh; Isle of Man.

Subglobose, umbilicus very small, rounded; shell with fine crenulated, reticulated, bent, transverse striæ. These are magnified at fig. 8. Some varieties are more globular than the figure. Septa as in the preceding.

G. obtusus. Ph. Pl. XIX. fig. 10—13. Black Hall in Bolland.

Subglobose, with flattish sides, and broad back: umbilicus very small, shell with delicate transverse and a few longitudinal striæ, and internal slightly bent ridges; edge of the septa delicately marked and waved, dorsal lobe very short, dorsal sinuses acute, first lateral lobe rounded.

G. striolatus. Ph. Pl. XIX. fig. 14—19. In shale, Kulkeagh; near Enniskillen; in shale, High-Green-wood, near Todmorden.

Almost exactly similar to G. obtusus, but the sides less parallel: striæ very delicate; septa fig. 18, with very wide pointed dorsal sinuses, and very wide rounded lateral lobes. The adult shell almost exactly resembles XIX. 12; the series of younger forms may be seen by fig. 15, 16, 17. The very young shells are more globular, with a large acute edged umbilicus, straight constrictions, and straight delicate simple striæ. With age the shell flattens, the constrictions become slightly waved and then cease entirely, the umbilicus loses its angularity; the septa and striæ scarcely vary;—my Kulkeagh specimen has the dorsal sinuses, fig. 19, rather less wide, and its outline differs a little.

G. truncatus. Ph. Pl. XIX. fig. 20, 21. Bolland.

Very depressed, back (in adults) truncate; umbilicus open; fine transverse bent striæ. The outline of the mouth appears in fig 14.

G. foraminosus. Ph. Bolland.

Depressed, spirally striated, umbilicus very small.

G. micronotus. Ph. Pl. XIX. fig. 22, 23. Bolland.

Depressed, umbilicus small, rounded, striæ transverse, constrictions little bent; septa with dorsal lobe small, first lateral lobes large and rounded, their dorsal edges parallel.

G. implicatus. Ph. Pl. XIX. fig. 24, 25. Black Hall in Bolland.

Subglobose, shell delicately striated across; septa more numerous than in the last, less waved on the edge; first lateral lobes widely rounded, their dorsal edges parallel, dorsal lobe very small, dorsal sinuses rounded.

G. reticulatus. Ph. Pl. XIX. fig. 26—32. High-Green-wood; Holmfirth; Marsden; Wyersdale; Flasby.

Adult depressed, back angulated, umbilicus angular, shell crenulato-striate. Young subglobose, umbilicus rounded, shell with acute radiating forked striæ, crossed by fine spiral lines. Septa; dorsal lobe short, first laterals rounded, large, their dorsal edges parallel. Constrictions even in the youngest much bent; greatly bent in the old. In old specimens the cast of the inside is very much undulated. Fig. 31, 26, and 27, give the changes of aspect; 30, the striæ when young; 32, the same when old; 29, the septa. 28, the section across the centre.

G. excavatus. Ph. Pl. XIX. fig. 33, 35. Bowes; Bolland; Flasby.

A shell closely allied to the preceding if not the same; the lateral sinus of the septa more acute; the young destitute of spiral striæ; edge of umbilicus acute, surface of old shells not angular.

G. Listeri. (Ammonites, Sow.) Pl. XX. fig. 1. Halifax; near Sheffield; near Colne; Holmfirth, Saddleworth.

Spheroidal, umbilicus wide, acute, its edges plaited, crenate or dentate; shell transversely striated, most distinctly so when young. Constrictions nearly direct; dorsal lobe double, dorsal sinus angular, deep, first lateral lobe ample, very round, lateral sinus angular, deep. The septa of the young differ but little from those of the old shells, except in the blunting of the angles as I have found by breaking several fine specimens from Halifax.

G. bidorsalis. Ph. Pl. XX. fig. 2, 3, 4. In shale, Woodfold.

Subglobose, umbilicate; with sigmoidal sharp radii, crossed by spiral striæ; lateral lobes and sinus round, dorsal lobe double, *each part divided.* The form of the septa distinguishes it from the young of G. variabilis.

G. platylobus. Ph. Pl. XX. fig. 5, 6. Bolland.

Subglobose, umbilicus moderate, crenate, shell with obsolete spiral striæ, constrictions direct, sutural lobes and sinuses rounded; dorsal lobe wide.

G. stenolobus. Ph. Pl. XX. fig. 7, 8, 9. Bolland.

Subglobose, umbilicus moderate, shell minutely rugose, constrictions direct: sutural lobes and sinuses rounded, dorsal lobe narrow.

G. nitidus. Ph. Pl. XX. fig. 10, 11, 12. Ribble river.

Subglobose, umbilicus wide, angular; striæ slightly bent, prominent, forked.

(Traces of spiral lines.) Septa peculiar in form; dorsal lobe simple, and short, second lateral lobe acute.

G. Gibsoni. Ph. Pl. XX. fig. 13—18. High-Green-wood.

Discoid, with bent acute radii prominent on the marginal and forked on the dorsal region. In older shells the whorls become continually more involute and gibbous, the young are flatter with apparent whorls. No spiral striæ, a few curved constrictions. This remarkable fossil resembles ammonites of the oolitic formation. N. natural size, the others magnified three times.

G. vesica. Ph. Pl. XX. fig. 19. 20. 21. Black Hall in Bolland; Kulkeagh shale.

Subglobose, with very rounded umbilicus; delicate transverse striæ; septa, with rounded and low undulations. The young differ but little. Dorsal sinuses very shallow.

G. calyx. Ph. Pl. XX. fig. 22, 23. High-Green-wood; Black Hall; Kulkeagh.

Young, discoideo-cylindrical, glabrous, with delicate transverse striæ, umbilicus wide, acute, (often crenate at the edges); volutions many; aperture flat-lunulate, constrictions direct. Septal undulations round, dorsal lobe and sinuses forming a waved transverse line. (The adult form is unknown to me.)

G. mutabilis. Ph. Pl. XX. fig. 24, 25, 26.

Young, discoideo-cylindrical, glabrous, umbilicus wide acute, not crenate; constrictions direct. Adult, subglobose, umbilicus rounder, narrower, constrictions direct. (First lateral lobe very narrow?)

G. Gilbertsoni. Ph. Pl. XX. fig. 27—31.

Depressed, outline elliptical, umbilicus small, glabrous with much bent striæ. Septa numerous; their lobes and sinuses round; dorsal sinus wide and double, lateral sinus simple.

G. Looneyi. Ph. Pl. XX. fig. 32, 33, 34, 35. High-Green-wood.

Depressed, glabrous, umbilicus minute, striæ sigmoidal, aperture elliptical. Septa numerous; *the dorsal and lateral sinuses wide and double*, (in young shells merely waved.)

G. paucilobus. Ph. Pl. XX. fig. 36, 37, 38.

Depressed, aperture elliptical, umbilicus very small, septa with all the lobes and sinuses round; the first lateral very large. (Differs from G. implicatus in the lateral sinus.)

G. Henslowi. Sow. Min. Conch. t. 262. Isle of Man; Ecton in Staffordshire; Pl. XX. fig. 39.

Discoid, sides flat, back rounded, inner whorls exposed, septa with four lateral lobes and three sinuses, all sole-shaped; dorsal sinus single, central, acute.

"sinus" = lobe
"lobe" = saddle

G. cyclolobus. Ph. Pl. XX. fig. 40, 42. Bolland.

Discoid, sides flat, back broad, inner whorls half concealed; septa with four round lateral lobes, a small double dorsal lobe, and small acute dorsal sinuses; the first lateral sinus double, the others simple, all round.

G. mixolobus. Ph. Pl. XX. fig. 43—47. Bolland.

Discoid, whorls elliptical, the inner ones a little concealed; septa with four rounded lateral lobes; the first lateral sinus double pointed, second, single pointed, dorsal lobes and sinuses pointed.

G. serpentinus. Ph. Pl. XX. fig. 48—50. Black Hall in Bolland.

Discoid, whorls all exposed, aperture nearly circular, delicate transverse striæ; septa approximate with three round lateral lobes; two round lateral sinuses, a central acute dorsal sinus.

G. spirorbis. Gilb. Pl. XX. fig. 51—55. Black Hall.

Discoid, whorls seven or more, round or oval, half concealed, coiled like a watch spring, finely striated across, as if wrapped with silk; sutural line exangulate. The young are globular.

G. rotiformis. Ph. Pl. XX. fig. 56, 57, 58. Bolland; Kulkeagh.

Discoid, whorls many, angular, half concealed like the last, bearing a truncated keel, and radiating furrows. Septa as in the last.

G. vittiger. Ph. Pl. XX. fig. 59, 60. Bolland.

Lenticular; back bearing a truncated keel, inner whorls more than half concealed.

G. intercostalis. Ph. Pl. XX. fig. 61, 62. Bolland.

Discoid, whorls costato-tuberculated on the sides, round on the back; with spiral intercostal striæ.

G. carina. Ph. Pl. XX. fig. 63, 64. Bolland.

Lenticular, back carinated, smooth.

G. evolutus. Ph. Pl. XX. fig. 65, 66, 67, 68. Flasby, &c.

Volutions apparent, their section round in young, oblong in old whorls; septa with a deep acute dorsal sinus, and obtuse angled first lateral lobe.

ORTHOCERAS. An extinct genus, unknown (in Great Britain at least) above the coal formation.

O. cinctum. Sow. Pl. XXI. fig. 1. Bolland; Castleton; Queen's County.

Elongate, section a very short ellipse, siphuncle central; septa distant; shell girt with fine undulating raised lines.

O. giganteum. Sow. Pl. XXI. fig. 3. Flasby; Bolland; Closeburn; Kildare.

Elongate, section circular, siphuncle a little excentric; septa numerous, regularly

concave. In a magnificent specimen belonging to Mr. Gilbertson, and in another in the Museum of the Yorkshire Philosophical Society, the siphuncle is expanded between the septa and its external surface there reticulated.

O. filiferum. Ph. Kulkeagh.

Elongate, septa rather distant, siphuncle nearly central; shell girt with fine regular thread-like striæ.

O. ovale. Ph. Castleton; Queen's County.

Elongate, section broad-oval, siphuncle a little excentric, septa without wave.

O. unguis. Ph. Pl. XXI. fig. 2. Bolland.

Suddenly arched toward the blunt end; section circular.

O. fusiforme. Sow. Pl. XXI. fig. 14, 15. Bolland; Kildare.

Pyriform, arched in the smaller part, tumid near the aperture; section oval, siphuncle one-third of the diameter from the edge, shell smooth. In the specimen figured, the large projecting plate with its plane parallel to the axis, and to the longer diameter of the shell, is covered on the convex side by a white laminated friable inner shell, (a) very analogous to the 'bone' of Sepia officinalis and to the lower laminæ of Belem. quadratus. My Kildare specimen does not shew it.

O. undulatum. Sow. Pl. XXI. fig. 8. Bolland; Castleton; Cumberland.

Section broad-oval; septa numerous, oblique, flattish, their edges rising with a wave on each side; siphuncle near the upper broad edge.

O. Breynii. Mart. t. 39. Sow. t. 60. Kulkeagh; Bowes.

Section long-oval, the siphuncle in one focus, near the higher edge; septa very oblique, approximate, shallow.

O. inequiseptum. Ph. Pl. XXI. fig. 7. Bolland.

Section round, septa very distant in the young shell.

O. arcuatum. Ph. Clane, Kildare.

A short conical shell, arched to the small end, with frequent septa, the siphuncle marginal on the convex side of the curve.

O. Steinhaueri. Sow. Pl. XXI. fig. 5. Bolland; Halifax, in coal shale.

Elongate, section circular, septa distant, very concave; siphuncle marginal, shell annuloso-striate.

O. angulare. Ph. Pl. XXI. fig. 4. Bolland; High-Green-wood.

Subcylindrical with a few longitudinal furrows; septa very distant.

O. reticulatum. Ph. Pl. XXI. fig. 11 (cast). Bolland.

Elongate, section circular, septa distant; surface annulated, and reticulated with moniliform lines.

O. annulatum. Sow. Pl. XXI. fig. 9, 10. Bowes; Kulkeagh; High-Green-wood; Northumberland.

Section a little oval; siphuncle excentric toward the broader side; shell marked with prominent annular ridges, and intervening waved striæ. α. subcylindrical; β. conical; γ. conical and curved.

O. rugosum. Flem. Pl. XXI. fig. 16. Northumberland.

Subcylindrical (or suddenly tapering), with annular waved rather distant ridges, tuberculated by many longitudinal echinated lines.

O. dentaloideum. Ph. Pl. XXI. fig. 12. Bolland.

Elongate, curved, with many small longitudinal ridges and furrows (less tapering than the next).

O. Gesneri. Mart. XXI. fig. 6. Bolland; Middleton Tyas; Cumberland; Northumberland; Derbyshire; Isle of Man.

A curved conical shell, with about thirty longitudinal acute ridges and rounded furrows; the section slightly oval, the siphuncle nearly marginal.

O. paradoxicum. Sow. t. 457. Kildare.

Figure arched; section deltoidal, back concave, sides convex, latero-dorsal edges truncate, and margined by a dorsal and a lateral furrow; delicate longitudinal striæ on the back and exterior part of the side; transverse striæ and sutures retroflexed on the back, siphuncle nearly central.

REMAINS OF CRUSTACEA.

TRILOBITES.

The following species are apparently sufficiently related to the genus asaphus of Brogniart, to allow of being ranked with it, until the whole subject of these curious fossils shall be re-examined, and the numerous species mentioned by Dalman, Greene, &c. rigorously compared with those here produced and others which are to appear in Mr. Murchison's expected volume.

A. quadrilimbus. Ph. Pl. XXII. fig. 1, 2. Bolland; Ireland.

Fig. 1. *The head.* Margin quadrato-carinate, minutely striated; surface smooth; eyes very minutely reticulated. 2. Abdomen.

A. obsoletus. Ph. Pl. XXII. fig. 3—6. Bolland; Kildare.

Abdominal lobes ventricose; transverse undulations obtuse; surface smooth, with undulating lines; *the limb with oblique undulating striæ;* head finely striated in undulated lines, roundish and lumpy.

A. granuliferus. Ph. Pl. XXII. fig. 7. Bolland; Tyrone; Florence Court.

Surface very minutely granulated; limb not striated.

A. seminiferus. Ph. Pl. XXII. fig. 8, 9, 10. Derbyshire; Bolland.

Head poroso-granulated, mesial lobe bisulcate on the sides, and bituberculated at the base; *abdomen* with tumid lobes; ribs roughened with eight or ten unequal prominent subglobose puncta; limb not striated. First segment of the middle lobe mucronate.

A. gemmuliferus. Ph. Pl. XXII. fig. 11. Bolland; Aldstone moor; Mendip; Kildare; Dublin.

Each abdominal lobe ornamented by six longitudinal lines of elevated puncta; the transverse furrows undulate the limb; (the cast is nearly smooth.) I suppose Brongniart's fig. 12, Pl. IV. to represent this species.

A. truncatulus. Ph. Pl. XVII. fig. 12, 13. Florence Court.

Depressed; mesial lobe of the head quadrisulcate, bituberculate; the eyes lunate; limb continuous, truncate, with undulating parallel striæ; six lines of elevated puncta on the abdominal lobes.

A. raniceps. Ph. Pl. XXII. fig. 14, 15. Bolland.

Limb rounded, with six imbricating striæ; eyes oblongo-lunate *very minutely* reticulated): surface smooth, head depressed.

A. globiceps. Ph. Pl. XXII. fig. 16—20. Bolland; Kildare.

Limb quadrate, with four imbricating striæ; eyes lunate on a globular projection; head globular. (This agrees better than any other which I have seen with E. Derbiensis of Martin, t. 45 * 1.)

MISCELLANEOUS CRUSTACEA.

Pl. XXII. fig. 21, 22. Supposed to be a portion of the claw of some crustaceous animal.

Pl. XXII. fig. 23, 24. Cypridiform shell. Bolland.

Pl. XXII. fig. 25. Agnostus? radialis. Ph. Bolland.

Ribs radiating, with acute puncta; abdomen mucronate.

FISHES.

Ichthyodorulites occur in Northumberland and in Shropshire. Teeth are found in Northumberland, at Bristol, Moulton, Richmond, Orton, in Tyrone, &c., but the examination of them belongs to M. Agassiz. A very extraordinary and beautiful fossil, which I suppose to belong to the vertebral division of the animal kingdom, is in the possession of Mr. Cooke of Wigton.

SUMMARY OF ORGANIC REMAINS.

		No. of Species mentioned in this Work.	*No. of Species figured in this Work.*	*No. of figures in this Work.*	*No. of Species named by the Author.*
Zoophyta	Polyparia	41	37	95	34
	Crinoidea	40	38	65	39
	Echinida	3	0	0	2
Mollusca	Conchif. Plagim.	32	31	33	27
	Conchif. Mesom.	24	24	28	17
	Brachiopoda	100	94	129	66
	Gasteropoda	91	89	97	79
	Cephal. Monoth.	10	10	16	2
	Cephal. Polythal.	69	59	156	46
Crustacea	Trilobites	8	8	20	8
	Miscellaneous	2	2	3	2
		420	392	642	322

Annulosa, too imperfect to be described, very few species.
Fishes, referred to M. Agassiz, very few species.

LIST OF LOCALITIES OF FOSSILS.

Locality.	*Group of Strata in which the Fossils occur.*	*Authority for the Locality.*	*No. of Species mentioned in this Work.*
Addleburgh, Wensleydale	Middle of Yoredale limestones	Phillips, Murch.	1
Ashfell, nr. Kirby Stephen	Top of lower scar limestone	Smith, Phillips	6
Ashford, Derbyshire ...	Black beds and top of lower scar limestone. ...	Martin, Gilbertson	2
Aldstone moor ...	Middle of Yoredale limestones and cherts ...	Phillips ...	3
Allenheads, Northumb.	Upper part of Yoredale rocks	Newc. N. Hist. Soc.	1
Alport, Derbyshire ...	Lower scar limestone	E. Barker ..	1
Arran, Isle of ...	Limestone alternating with red sandstones, &c.	Phillips ..	5
Askrigg	Base of Yoredale limestone	Phillips ...	1
Belmore mountain, near Enniskillen	Base of the upper Irish limestone	Phillips ...	1
Black Hall, in Bolland	Black beds on lower scar limestone... ...	Gilbertson ...	1
Bolland	Top of lower scar limestones	Gilbertson ...	258
Bowes	Near top of Yoredale rocks	Dr. Moore ...	10
Bristol	Lower scar limestone	Miller, Phillips ...	10
Brough, Westmoreland	Limestones alternating with red sandstones ...	Phillips ...	3
Broughton (Skipton) ..	Upper part of lower scar limestone	Lister	1
Burton fell, Cumberland	Lower scar limestone	Salmond ...	1
Buxton	Lower scar limestone	Martin ...	1

Caldy Island...	Lower scar limestone	Sowerby, Llwyd ...	2
Carry Lee, Lancashire...	Coal shale	Gilbertson	1
Castleton, Derbyshire ...	In lower scar limestone	Phillips...	11
Chipping (Bolland) ...	Top of lower scar limestone	Gilbertson	3
Clattering dykes ...	Top of lower scar limestone	W. V. Harcourt ...	1
Clithero ...	Top of lower scar limestone	Phillips	1
Closeburn (Dumfries)	Limestone alternating with red sandstone	Menteith	1
Coalbrookdale ...	Coal measures	Prestwich	10
Colne, near ...	Coal measures	Looney ..	1
Colsterdale ...	Millstone grit series	Danby ...	5
Conishead, Lancashire...	Lower scar limestone	Phillips...	2
Coniston (Skipton) ...	Top of Craven limestone	Gilbertson	1
Cork ...	Lower Irish limestone	Sowerby	2
Carlingford ...	Lower Irish limestone	Griffith	1
Coverdale ...	Yoredale rocks	Phillips...	2
Crooklands, nr. K. Lonsd.	Lower scar limestone	Phillips	1
Cumberland ...	Lower scar and Yoredale rocks	Cooke, Phillips ...	6
Derbyshire ...	Lower scar limestone	Mart. Gilb. Sow....	31
Dublin ...	Lower Irish limestone	Sowerby, &c.	4
Dentdale ...	Top of lower scar limestone	Phillips	1
East Witton ...	Top of the Yoredale limestones	Phillips...	1
Ecton, Staffordshire ...	'Limestone shale'	Phillips...	1
Enniskillen ...	Lower Irish limestone		2
Fermanagh ...	Lower Irish limestone	Col. Montgomery	3
Flasby, near Skipton ...	Shale of the Yoredale series	Preston...	5
Flintshire ...	Lower scar limestone	York Phil. Soc. ...	1
Florence Court, near Enniskillen	Base of the upper Irish limestone	Lord Cole, Sir P. Egerton, Phillips	25
Frome, Somersetshire ...	Lower scar limestone	Col. Houlton	1
Fountains Fell ...	Shale of the Yoredale series	Phillips...	3
Gordale ...	Lower scar limestone	Phillips	1
Greenhow hill ...	Lower scar limestone	Phillips..	9
Halifax ...	Lower coal shales	Rawson, Phillips ...	2
Haltwhistle ...	Millstone grit series	Newc. N. H. Soc.	1
Harelaw, Northumberland	Yoredale rocks	C. V. Harcourt ...	9
Harrogate ...	Millstone grit series	Phillips	8
Hawes ...	Base of Yoredale rocks & top of lower limestone	Phillips	10
Hesket-Newmarket ...	In lower scar limestone	Cooke, Phillips ...	2
High-Green-wood, Todmorden	'Limestone shale'	Gibson ...	10
Holmfirth ...	'Limestone shale'	Looney ...	3
Hudswell, near Richmond	Millstone grit series	Phillips	1
Ireland ...	Lower Irish limestone	Sowerby, &c.	15

Kendal	Lower scar limestone	Gilb. N. H. Soc. ...	4
Kettlewell	Lower scar limestone	Phillips	2
Kildare County ...	Lower Irish limestone	H. Hutton ...	29
Kirby Lonsdale ...	Yoredale rocks and top of lower scar limestone	Phillips	20
Kulkeagh, nr. Enniskillen	Shale over the top limestone (Yored. series?)	Lord Cole, Sir P. Egerton, Phillips	3
Lee, Northumberland ...	Yoredale rocks	C. V. Harcourt ...	2
Linlithgow	Lower scar limestone	Dr. Fleming ...	3
Lofthouse, Nidderdale...	Lower scar limestone	Phillips	1
Man, Isle of	Lower scar limestone	Henslow, Gilb. ...	13
Marsden	In 'limestone shale'	S. Hailstone ...	2
Menai Bridge ...	Lower scar limestone	Sowerby	1
Mendip	Lower scar limestone	Parkinson, Phillips	11
Middleham	Top of Yoredale rocks	Phillips	1
Middleton Tyas ...	Top of Yoredale limestone	Phillips	1
Moughton Scar, Craven	Base of lower scar limestone	Phillips	1
Moulton, Catterick Bridge	Top of Yoredale rocks	Phillips	2
Northumberland ...	Yoredale rocks	C.V.Harcourt, N.H.S.	50
Orton	Top of lower scar limestone	Phillips	4
Otterburn, Northumb....	In divided lower limestones	N. H. Soc. ...	15
Pateley Bridge ...	Millstone grit series	Phillips	3
Pembrokeshire ...	Lower scar limestone	Yorksh. Phil. Soc.	1
Penyghent	Base of Yoredale limestones	Phillips	4
Queen's County ...	Lower Irish limestone	Dr. Sadleir ...	16
Ravonstonedale... ...	Limestone alternating with red sandstone ...	Phillips	2
Redesdale, Northumb. ..	Divided lower limestones	N. H. Soc. ...	1
Ribblehead	Top of lower scar limestone	Phillips	4
Richmond	Millstone grit series	Phillips	4
Rokeby	Top of Yoredale limestones and shales ...	Salmond... ...	2
Saddleworth	Limestone shale	Looney	1
Settle	Lower scar limestone	Sowerby, Hamerton	3
Sheffield	Coal shale	Phillips	1
Stradone, near Cavan ...	Lower Irish limestone	Phillips	2
Teesdale	Lower part of Yoredale limestones	Phillips	1
Tideswell	Lower scar limestone	Martin, Sowerby ...	2
Todmorden	'Limestone shale'	Gibson	1
Ulverstone	Lower scar limestone	Gilbertson ...	1
Veynal	Lower scar limestone	Smith	1
Whitewell (Bolland) ...	Lower scar limestone	Gilbertson, Phillips	11
Winster	Lower scar limestone	Martin, Sow., &c....	1
Wolsingham	Top of Yoredale rocks	N. H. Soc. ...	1
Woodfold	'Limestone shale'	Gilbertson ..	1
Wrekin	Lower scar limestone	W. Smith ...	2
Wyersdale	In Bolland shale	Phillips	2

VIEW OF THE DISTRIBUTION OF THE ORGANIC REMAINS PREVIOUSLY DESCRIBED IN THE STRATA OF THE CARBONIFEROUS SYSTEM.

It is necessary to observe that no organic fossils have been noticed in this Work which the Author has not seen and examined; all are from the mountain limestone and millstone grit, except a few remarkable shells found in a marine calcareous bed interstratified with the estuary deposits of the coal formation of Yorkshire, and others from Coalbrookdale and Linlithgowshire, which are found in coalfields probably coeval with the Yoredale rocks. In stating the Localities the greatest care has been taken to exclude every thing doubtful; in fact the Author *has seen specimens* of the species indicated, from the localities named, and the authorities for such fossils having been actually obtained from these localities are either the discoverers themselves, or the records of three public museums. These notices of localities might have been greatly expanded, but they would not in that case have been so trustworthy: for nothing is less easy than to determine positively on the identity of a fossil species by merely looking at a single specimen, while hastily reviewing a whole collection; still less is it safe to quote from carelessly executed engravings, or negligently recorded localities; and it would be utterly subversive of all accuracy to copy the names which are ostentatiously placed on the specimens of ill-arranged private or public collections.

	Polyparia.	*Crinoidea.*	*Echinida.*	*Plagimyona.*	*Mesomyona.*	*Brachiopoda.*	*Gasteropoda.*	*Cephalopoda.*	*Crustacea.*	*Total.*
Coal formation	—	1	—	1	2	3	—	7	—	14
Millstone grit	6	—	—	1	5	4	—	—	—	16
Yoredale rocks	8	1	2	11	5	29	9	34	1	100
Lower scar limestone	40	40	3	26	25	96	91	61	8	390
Alternating limestone and red sandstone	3	—	1	—	—	—	—	2	—	6

Of fourteen species in the coal formation twelve occur in lower scar limestone. The sixteen species in millstone grit occur more abundantly in lower scar limestone.

Of one hundred species of fossils in the Yoredale rocks seventy-two occur also in the lower scar limestone.

Zoophyta.	Plag. & Mesom.	Brachiopoda.	Gasteropoda.	Cephalopoda.	Trilobites.
10 in 11.	10 in 16.	25 in 29.	9 in 9.	17 in 34.	1 in 1.

The six specimens mentioned in the alternating red sandstones and limestones occur in the lower scar limestone, more abundantly.

It appears to be in the upper part of the lower scar limestone that the greatest number of fossils of all kinds occur: they grow continually less and less plentiful as we ascend in the series of the Yoredale rocks, millstone grit, and lower part of the coal measures. In the upper parts of the coal series *all* the species vanish. In the magnesian limestone which lies over the coal, some very analogous but probably not identical species are observed; above this the predominant features of the whole series of marine organic forms of the carboniferous period disappear.

REFERENCE TO THE PLATES OF ORGANIC REMAINS.

The specimens figured in the following plates are chiefly in the collections of Mr. Gilbertson and the Author. Several are preserved in the Museums of the Yorkshire Philosophical Society, the Natural History Society of Newcastle, and the Geological Society of London; others occur in the cabinets of Sir Philip Egerton, Bart.,—Rev. S. Smyth, and Dr. Greene of Dublin,—Mr. Gibson of Hebden Bridge,—Mr. Looney of Manchester,—Dr. Moore of Preston,—Mr. Bean of Scarborough,—Mr. Prestwich of South Lambeth,—and others. Some of them now in my possession were given me by Lord Cole, Mr. H. Hutton and Dr. Sadleir of Dublin. I have thought it useful, in some cases, to mark by abbreviations not only the collection where the specimen is deposited, but others in which I have seen the same species; it being always understood that the cabinet first referred to is that from which my drawing was taken.

Abbreviations used.

S.—Sowerby.
P.—Phillips.
G.—Gilbertson.
Y. P. S.—Yorkshire Philosophical Society.
N. H. S.—Natural History Society of Newcastle.
G. S.—Geological Society of London.

Plate I.—Zoophyta, page 198, &c.

Fig.	
1—6.	Retepora membranacea, P. *Mus. G., P.*
7—10.	R. flabellata, P. *Mus. P., G.*
11, 12.	R. flustriformis, P. *Mus. P.*
13—15.	R. pluma, P. *Mus. P., G.*
16—18.	R. undulata, P. *Mus., P.*
19, 20.	R. polyporata, P. *Ditto.*
21, 22.	R. irregularis, P. *Ditto.*
23—25.	R. tenuifila, P. *Ditto.*
26—30.	R. laxa, P. *Mus. Smyth, G., P.*
31—33.	R. nodulosa, P. *Mus. P.*
34, 35.	Millepora rhombifera, P. *Mus. G., P.*
36—39.	M. interporosa, P. *Mus. P.*
40—42.	M. spicularis, P. *Mus. P., G.*
43—46.	M. oculata, P. *Mus. P.*
47, 48.	Flustra parallela, P. *Ditto.*
49—57.	Calamopora tumida, P. *Mus. P., N.H.S., Y. P. S., G. S.*
58—60.	C. dentifera, P. *Mus. G.*
61, 62.	C. parasitica, P. *Ditto.*
63, 64.	C. incrustans, P. *Ditto.*
65.	Gorgonia? *Mus. G.*

Plate II.—Zoophyta, page 201, &c.

1.	Syringopora geniculata, P. *Mus. P., Y.P.S.*
2.	S. ramulosa, Goldf. *Mus. G., P., Y.P.S.*
3—5.	Favosites capillaris, P. *Mus. P., Y.P.S.*
6—8.	F. septosus, Flem. *Mus. Y.P.S.*

Fig.
9, 10. Hydnopora? cyclostoma, P. *Mus. Y.P.S.*
11—13. Lithodendron sexdecimale, P. *Mus. P., Y. P. S., N. H. S. N., &c.*
14, 15. L. irregulare, P. *Mus. P., Y. P. S.*
16, 17. L. faciculatum, Fl. P. *Mus. P., Y.P.S., &c.*
18. L. longiconicum, P. *Mus. Y.P.S., G.S.E., Lord Cole.*
19, 20. L. sociale, P. *Mus. P., Y. P. S.*
21, 22. Cyath. basaltiforme P. *Mus. P., Y. P. S., G. S. W., &c.*

Fig.
23. Turbinolia fungites, Auct. *Mus. P., Y.P.S., N. H. S. N., G. S., &c. &c.*
24. Amplexus Sowerbii, P. *Mus. P., G., Y. P. S., &c.*
25, 26. Cyath. regium, P. *Mus. P., Y. P. S.*
27, 28. Cy. crenulare, P. *Mus. Y. P. S., &c.*
29. Calamop.? megastoma, P. *Mus. G.*
30. Calamop.? tenuisepta, P. *Ditto.*

Plate III.—Crinoidea, page 203, *&c.*

1, 2, 3. Pentremites inflatus, Gilb. *Mus. G., P.*
4, 5, 5.* Pen. acutus, Gilb. *Mus. G., P.*
6, 7, 8. Pen. ellipticus, Sow. *Mus. G., P., Y.P.S.*
9. Pen. orbicularis, Gilb. *Mus. G.*
10. Pen. Derbiensis, Sow. *Ditto.*
11, 12. Pen. oblongus, Gilb. *Ditto.*
13. Pen. angulatus, Gilb. *Ditto.*
14, 15. Platycrinus lævis? Mill. *Mus. Bean, G., P., Y. P. S.*
16. Pl. granulatus, Mill. *Mus. G. P.*
17. Pl. tuberculatus, Mill. *Ditto.*
18. Pl. laciniatus, Gilb. *Mus. G.*
19—21. Pl. ellipticus, P. *Mus. G., P.*
20. Pl. rugosus, Mill. *Mus. G., Y.P.S., P.*
22, 23. Pl. gigas, Gilb. *Mus. G.*
24—26. Pl. elongatus, Gilb. *Mus. G., P.*
25. Platycrinus contractus, Gilb. *Mus. G.*
27. Cyathocr. conicus, P. *Ditto.*
28. Cy. mammillaris, P. *Ditto.*
29. Cy. bursa, P. *Ditto.*
30—32. Cy. quinquangularis, Mill. *Mus. G., P., Prestwich.*
33. Magnified joints of arms and fingers of fig. 38, *Mus. G.*
34. Cy. distortus, Gilb. *Ditto.*
35. Cy. calcaratus, P. *Ditto.*
36, 37. Cy. ornatus, P. *Ditto.*
38. Arms of a Cyathocrinus, *Ditto.*
39. Poteriocrinus? Egertoni, P. *Mus. Sir P. Egerton.*
40. Poteriocrinus? nobilis, P. *Mus. G.*

Plate IV.—Crinoidea, page 204, *&c.*

1. Poteriocrinus impressus, P. *Mus. G., P.*
2. Pot. granulatus, P. *Mus. G., P., N.H.S.N.*
3. Pot. conicus, P. *Mus. G.*
4. Pot. granulatus, P. *Mus. G., P, N.H.S.N.*
5. Young Poteriocrinus, Gilb. } *Mus. G.*
6. Magnified joints of Ditto. }
7. Scapular surface of P. conicus, P. *Ditto.*
8. Pot. granulatus, P. } *Ditto*
9, 10. Scapular surface of Ditto. }
11. Columnar joint of Poterioer.
12, 13. Synbathocrinus conicus, P. *Mus. G., P., &c.*
14. Outside of Euryocr. concavus, P. *Mus. G.*
15. Inside of Euryocr. concavus, P. *Mus. G.*
16. Actinocrinus triaconta-dactylus, Mill. *Mus. Bean, G., P., Y. P. S., &c.*
17. Act. polydactylus, Mill. *Mus. Bean, G., &c.*
18. Joints of body and Arms of Ditto, *Ditto.*
19. Act. Gilbertsoni, Mill. *Mus. Bean, G., P.*
21. Act. tessellatus, P. *Mus. Col. Houlton.*
22. Gilbertsocrinus calcaratus, P. *Mus. G.*
23. G. mammillaris, P. *Ditto.*
24, 25. G. bursa, P. *Ditto.*
26, & 29. Act. globosus, P. *Ditto.*

Plate V.—Conchifera Plagimyona, page 208, *&c.*

Fig.		Fig.	
1.	Corbula? senilis, P. *Mus. P., Y. P. S.*	16.	Nucula undulata, P. *Mus. G.*
2.	Sanguinolaria? angustata, P. *Mus. G.*	17.	N. claviformis? Sow. *Mus. Y. P. S., G., N. H. S. N.*
3.	S. tumida, P. *Mus. P.*		
4.	S. arcuata, P. *Mus. Y. P. S.*	18.	Isoc.? unioniformis, P. *Mus. G.*
5.	S. sulcata, P. *Mus. N.H.S.N., Y.P.S.*	19.	Cucullæa obtusa, P. *Ditto.*
6.	Solemya primæva, P. *Mus. Y. P. S., N. H. S.*	20.	C. arguta, P. *Ditto.*
		21.	Modiola lingualis, P. *Mus. P.*
7.	Venus elliptica, P. *Mus. Y. P. S.*	22.	M. squamifera, P. *Mus. G.*
8.	V. parallela, P. *Mus. G.*	23.	M. granulosa, P. *Mus. Y. P. S.*
9.	Isocardia oblonga, Sow. *Mus. G., P., Smyth.*	24.	M. elongata, P. *Mus. G.*
		25.	Cypricardia glabrata, P. *Ditto.*
10.	Cypricardia rhombea, P. *Mus. G.*	26.	Pleurorhynchus hibernicus, Sow., P. *Mus. P., G., &c.*
11.	Nucula luciniformis, P. *Mus. G., Y.P.S.*		
11 *a.*	N. brevirostris, P. *Mus. Y. P. S.*	27.	P. minax, P. *Mus. G., P., &c.*
12.	Lucina? laminata, P. *Mus. G.*	28.	P. elongatus, P. *Ditto.*
13.	Isocardia? axiniformis, P. *Mus. Y.P.S., N.H.S., Mr. Cooke of Wigton.*	29.	P. armatus, P. *Mus. P.*
		30,31,32.	P. trigonalis, P. *Mus. G.*
14.	Nucula cuneata, P. *Mus. G.*	33.	Unknown genus, *Mus. P.*
15.	N. tumida, P. *Mus.G.,Y.P.S.,G.S.E.,&c.*		

Plate VI.—Conchifera Mesomyona, page 211, *&c.*

1.	Pinna inflata, P. *Mus. G.*	15.	Pecten ellipticus, P. *Mus. G., N.S.H.N.*
2.	P. costata, P. *Mus. G., P.*	16.	P. hemisphericus, P. *Mus. G.*
3, 4.	Inoceramus vetustus, S.*Mus.G.,Y.P.S.,P.*	17, 19.	P. dissimilis, Flem. *Ditto.*
5.	Avicula cycloptera, P. *Mus. G.*	18.	P. stellaris, P. *Ditto.*
6.	A. tessellata, P. *Mus. G., Y. P. S.*	20.	P. arenosus, P. *Mus. G., G.S.E., G.S.W.*
7.	Pecten granosus, S. *Mus. P.*	21.	P. plicatus? S. *Mus. G.*
8.	Avicula radiata, P. *Mus. G.*	22.	P. anisotus, P. *Ditto.*
9.	Gervillia squamosa, P. *Ditto.*	23.	Plagiostoma, P. *Mus.* Y. *P. S.*
10.	G. laminosa, P. *Mus. G., Y. P. S.*	24.	Pecten interstitialis, P. *Mus.P.,Y.P.S.,G.*
11.	G. laminosa, (cast of,) *Mus. G.*	25.	Avicula sublobata, P. *Mus. P.*
12.	G. lunulata, P. *Mus. G., P., Griffith.*	26.	Pecten deornatus, P. *Ditto.*
13.	G. inconspicua, P. *Mus. P.*	27.	P. simplex, P. *Mus. G.*
14.	Perna? *Mus. G.*	28.	P. fimbriatus, *Mus. P.*

Plate VII.—Producta, page 213, *&c.*

1.	Producta Martini, S. *Mus. G., P., Gibson, &c.*	4.	P. comoides, S. *Mus. G., Y.P.S., P., &c.*
		5.	P. Edelburgensis, P. *Mus. G., P.*
2.	P. costata et sulcata, S. *Mus. G., P.*	6.	P. aurita, P. *Ditto.*
3.	P. antiquata, S. *Mus. G., P., Y. P. S., Gibson, &c.*	7.	Young of the same, *Mus. G.*
		8.	P. quincuncialis, P. *Ditto.*

Fig.		*Fig.*	
9.	Producta concinna, S. *Mus. G.*	14.	Producta spinulosa, S. *Mus. G., Y.P.S.*
10.	P. analoga, P. *Ditto.*	15.	P. pustulosa, P. *Mus. G., P., Y. P. S.*
11.	P. pectinoides, G. *Mus. G., Y. P. S.*	16.	P. rugata, P. *Mus. G.*
12, 13.	P. mesoloba, P. *Mus. G., P.*		

Plate VIII.—Producta.

1.	Producta latissima, S. *Mus. P., N.H.S., Y. P. S.*	10.	Producta punctata, S. *Mus. G., Y.P.S., N. H. S., G., P.*
2.	P. scabricula, S. *Mus. Y.P.S., P., Prestwich, &c.*	11, 12.	P. fimbriata, S. *Mus. Y.P.S., G., P., &c.*
		13.	P. rarispina, P. *Mus. G., P.*
3.	P. muricata, P. *Mus. Y. P. S.*	14.	P. ovalis, P. *Mus. G.*
4.	P. plicatilis, S. *Mus. P.*	15.	P. granulatus, P. *Mus. G., P.*
5.	P. gigantea, S. *Ditto.* (reduced figure.)	16.	P. lirata, P. *Mus.*
6.	P. pugilis, P. *Ditto.*	17.	P. setosa, P. *Mus. Y. P. S.*
7.	P lobata, S. *Mus. P., N.H.S.N., Y.P.S.*	18.	P. depressa? S. *Mus. P.*
8.	P. margaritacea, P. *Mus. P.*	19.	P. Martini, S. *Mus. Y. P. S.*
9.	P. setosa, P. *Mus. Y. P. S.*	20.	P. scabricula? S. *Mus. G.*

Plate IX.—Spirifera, page 216, *&c.*

1—4.	Spirifera cuspidata, S. *Mus. G., P., Y. P. S., &c.*	10, 11.	Spirifera fusiformis, P. *Mus. G.*
		12.	Sp. triangularis, S. *Ditto.*
2, 3.	Sp. insculpta, P. *Mus. G. Dr. Henry.*	13.	Sp. attenuata, S. *Mus. G., P., &c.*
5.	Sp. senilis, P. *Mus. G.*	14.	Sp. bisulcata, S. *Mus. G., P., Prestwich.*
6.	Sp. crenistria, P. *Ditto.*	15, 16.	Sp. semicircularis, P. *Mus. G., P.*
7.	Sp. convoluta, P. *Ditto.*	17.	Sp. rotundata, S. *Ditto.*
8, 9.	Sp. rhomboidea, P. *Ditto.*	18, 19.	Sp. pinguis, S. *Ditto.*

Plate X.—Spirifera.

1.	Spirifera, duplicicosta, P. *Mus. G., P.*	14.	Spirifera mesoloba, P. *Mus. G.*
2.	Sp. integricosta, P. *Mus. G.*	15.	Sp. planosulcata, P. *Ditto.*
3.	Sp. planata, P. *Ditto.*	16.	Sp. elliptica, P. *Mus. G., P.*
4.	Sp. linguifera, P. *Ditto.*	17.	Sp. tæniata, S. *Mus. G., P., Y. P. S., &c.*
5.	Sp. ovalis, P. *Ditto.*	18.	Sp. expansa, P. *Mus. G.*
6.	Sp. trisulcosa, P. *Ditto.*	19.	Sp. glabristria, P. *Ditto.*
7.	Sp. triradialis, P. *Ditto.*	20.	Sp. imbricata, P. *Mus. G., P., Y. P. S., N. H. S.*
8.	Sp. sexradialis, P. *Ditto.*		
9.	Sp. decora, P. *Ditto.*	21.	Sp. squamosa, P. *Mus. G., P.*
10—12.	Sp. glabra, Mart. *Mus. G., P., &c.*	22.	Sp. globularis, P. *Mus. G.*
13.	Sp. symmetrica, P. *Mus. G.*		

Plate XI.—Brachiopoda, page 220, *&c.*

1.	Spirifera resupinata, S. *Mus. S., P., Y. P. S., &c.*	2.	Spirifera connivens, P. *Mus. G., P.*
		3.	Sp. filiaria, P. *Mus. G., P., N. H. S.*

Fig.

4. Spirifera arachnoidea, P. ***Mus.P.,N.H.S.***
5. Sp. radialis, P. ***Mus. P.***
6. Sp. papilionacea, P. ***Mus. G., N. H. S.***
7. Sp. septosa, P. ***Mus. P., Y. P. S.***
8. Sp. humerosa, P. ***Mus. P.***
9. Sp. elongata, P. ***Ditto.***
10—13. Orbicula nitida, P. ***Mus. P. Moore, Y. P. S., Prestwich, &c.***

Fig.

14. Lingula squamiformis, P. ***Mus. G.***
15. L. elliptica, P. ***Ditto.***
16. L. marginata, P. ***Mus. Moore.***
17—19. L. parallela, ***Mus. Y. P. S.***
20. Terebratula antiquata, P. ***Mus. G.***
21. T. ambigua, S. ***Mus. Y. P. S., N. H. S.***

Plate XII.—Terebratula, page 221, &c.

1. Terebratula hastata, S. ***Mus. G., P., Y. P. S.***
2. T. sacculus, Mart. ***Mus. G., P., Y. P. S., &c.***
3. T. pentaëdra, P. ***Mus. G., P.***
4—9. T. acuminata, S. ***Mus. G., P., &c.***
10—12. T. mesogona, P. ***Mus. G., P.***
13—15. T. reniformis, ***Ditto.***
16. T. pleurodon, P. ***Mus. G.***
17. T. pugnus, Mart. ***Mus. G., P., &c.***
18—20. T. rhomboidea, P. ***Mus. G.***
21—23. T. seminula, P. ***Mus. G.***
24. Terebratula excavata, P. ***Mus. G.***
25—30. T. pleurodon, P. ***Mus. G., P., Y. P. S.***
31, 32. T. sulcirostris, P. ***Mus. G.***
33, 34. T. flexistria, P. ***Ditto.***
35. T. tumida, P. ***Ditto.***
36. T. ventilabrum, P. ***Mus. G.***
37. T. proava, P. ***Ditto.***
38, 39. T. ventilabrum ? P. ***Mus. G.***
40, 41. T. radialis, P. ***Ditto.***

Plate XIII.—Gasteropoda, page 223, &c.

1, 2. Euomphalus catillus, M. ***Mus. G.***
3. E. calyx, P. ***Ditto.***
4. E. bifrons, P. ***Mus. G., P.***
5. E. cristatus, P. ***Mus. G.***
6. Cirrus pileopsideus, P. ***Ditto.***
7. C. tabulatus, P. ***Ditto.***
8. C. pentagonalis, P. ***Ditto.***
9. Turbo tiara, G. ***Mus. G., Moore.***
10. T. semisulcatus, P. ***Mus. G.***
11. T. biserialis, P. ***Ditto.***
12. Cirrus acutus, S. ***Mus. G., P., &c.***
13. Section of E. pentagonalis, S. ***Mus. G., &c.***
14. *Cirrus* spiralis, P. ***Mus. G.***
15. C. rotundatus, S. ***Mus. G., P., &c.***

Plate XIV.—Gasteropoda, page 223, &c.

1. Patella scutiformis, P. ***Mus. G.***
2. P. sinuosa, P. ***Ditto.***
3. P. mucronata, P. ***Ditto.***
4. P. curvata, P. ***Ditto.***
5. P. retrorsa, P. ***Ditto.***
6. P. lateralis, P. ***Ditto.***
7. Metoptoma pileus, P. ***Ditto.***
8. M. imbricata, P. ***Ditto.***
9. M. elliptica, P. ***Ditto.***
10. M. oblonga, P. ***Ditto.***
11. M. sulcata, P. ***Ditto.***
12, 13. Pileopsis trilobus, P. ***Mus. Henry, P., G.***
14. P. tubifer, S. ***Mus. G.***
15. P. striatus, P. ***Mus. G., N. H. S., P.***
16—18. Pileopsis neritoïdes, P. ***Mus. G.***
19. P. vetustus ? S. ***Mus. G., P.***
20. P. angustus, P. ***Mus. G.***
21—24. Natica ampliata, P. ***Mus. G., N. H. S.***
22. N. lirata, P. ***Mus. G.***
23. N. elliptica, P. ***Ditto.***
25. N. plicistria, P. ***Mus. G., P., &c.***
26—27. N. variata, P. ***Mus. G.***
28. N. elongata, P. ***Ditto.***
29. N. tabulata, P. ***Ditto.***
30. (Referred to in p. 224, as fig. 24,) N. planispira, P. ***Ditto.***
31. N. lirata, P. ***Ditto.***

Plate XV.—Pleurotomaria, page 226, &c.

Fig.		Fig.	
1.	Pleurotomaria carinata, S. *Mus. Sowerby.*	16.	Pleurotomaria fusiformis, P. *Mus. G.*
2.	P. flammigera, P. *Mus. G.*	17.	P. squamula, P. *Ditto.*
3.	P. tumida, P. *Ditto.*	18.	P. limbata, P. *Ditto.*
4.	P. expansa, P. *Ditto.*	19.	P. gemmulifera, P. *Ditto.*
5.	P. sulcatula, P. *Ditto.*	20.	P. excavata, P. *Ditto.*
6.	P. sulcata, P. *Ditto.*	21.	P. acuta, P. *Ditto.*
7.	P. depressa, P. *Ditto.*	22.	P. conica, P. *Mus. G., P.*
8.	P. inconspicua, P. *Ditto.*	23.	P. concentrica, P. *Mus. G.*
9.	P. strialis, P. *Ditto.*	24.	P. vittata, *Mus. G., N. H. S.*
10.	P. interstrialis, P. *Ditto.*	25.	P. tornatilis, P. *Mus. G.*
10 *a.*	P. monilifera, P. *Ditto.*	26.	P. helicoides, S. *Ditto.*
11.	P. atomaria, P. *Ditto.*	27.	P. ovoidea, P. *Mus. G., P., N. H. S.*
12.	P. sculpta, P. *Ditto.*	28.	P. glabrata, P. *Mus. G.*
13.	P. lirata, P. *Ditto.*	29.	P. biserrata, P. *Ditto.*
14.	P. undulata, P. *Ditto.*	30.	P. serrilimba, P. *Ditto.*
15.	P. abdita, P. *Mus. G., P.*	31.	Cirrus, probably C. rotundatus, S.

Plate XVI.—Gasteropoda, page 228, &c.

1.	Melania constricta, S. *Mus. G., P.*	10.	Buccinum rectilineum, P.
1 *a.*	M. sulculosa, P. *Mus. G.*	11, 21.	B. acutum, S. *Mus. G., N. H. S.*
2.	M. tumida, P. *Mus. G., P.*	12.	B. sigmilineum, P. *Mus. G.*
3.	M. scalarioidea, P. *Mus. G., N. H. S.*	13,22,23.	B. curvilineum, P. *Ditto.*
4.	Turritella tenuistria, P. *Mus. G.*	14.	B. vittatum, P. *Ditto.*
5.	T. spiralis, P. *Ditto.*	15.	B. globulare, P. *Ditto.*
6.	T. suturalis, P. *Ditto.*	16.	Rostellaria angulata, P. *Ditto.*
7.	T. tæniata, P. *Ditto.*	24.	A shell from Kirby Lonsdale, *Mus. P.*
8.	Buccinum ? parallele, P. *Ditto.*	25.	Turritella triserialis, P. *Mus. N. H. S.*
9,17,20.	B. imbricatum, S. *Ditto.*	26.	Melania rugifera, P. *Mus. Y.P.S., N.H.S.*

Plate XVII.—Cephalopoda, page 230, &c.

1—3.	Bellerophon Woodwardii, S. *Mus. G.*	17.	Nautilus dorsalis, P. *Mus. G.*
4.	B. apertus, S. *Mus. P., G.*	18, 25.	N. sulcatulus, P. *Mus. G., P., &c.*
5, 15.	B. costatus, S. *Mus. G., Y. P. S.*	19.	N. carinatus, S. *Mus. G.*
6, 7, 14.	B. tangentialis, P. *Mus. G., P.*	20, 28.	N. globatus, S. *Ditto.*
8.	B. spiralis, P. *Mus. Y. P. S , N. H. S., Moore.*	21. 22.	N. bistrialis, P. *Mus. G.*
9, 10.	B. tenuifascia, S. *Mus. G.*	23.	N. goniolobus, P. *Ditto.*
11, 12.	B. Urii, Flem. *Mus. Moore, G., N.H.S.*	24, (26 ? 27 ?)	N. tetragonus, P. *Mus. P., G.*
13.	B. decussatus, Flem. *Mus. G. Soc.*	29.	N. cyclostomus, P. *Mus. G., Gibson.*
16.	B. cornu arietis, S. *Mus. Y. P. S.*		

Plate XVIII.—Nautilus, page 231, *&c.*

Fig.		Fig.	
1, 2.	Nautilus dorsalis, P. *Mus. G., P.*	4.	Nautilus ingens, M. *Mus. G., Y. P. S.*
3.	N. cyclostomus, P. *Mus. G., Gibson.*		

Plate XIX.—Goniatites, page 233, *&c.*

1—3.	Goniatites striatus, S. *Mus.G.,P.,Y.P.S.*	20, 21.	Goniatites truncatus, P. *Mus. G.*
4—6.	G. sphæricus, S. *Mus. G., P., Y. P. S.*	22, 23.	G. micronotus, P. *Ditto.*
7—9	G. crenistria, P. *Mus. G., P.*	24, 25.	G. implicatus, P. *Ditto.*
10—13.	G. obtusus, P. *Mus. G.*	26—32.	G. reticulatus, P. *Mus. Gibson, Looney.*
14—19.	G. striolatus, P. *Mus. Gibson, P.*	33—35.	G. excavatus, P. *Mus. G., Y. P. S.*

Plate XX.—Goniatites, page 235, *&c.*

1.	Goniatites Listeri, S. *Mus.G., P., Looney, Y. P. S.*	40—42.	Goniatites cyclolobus, P. *Mus. G.* The locality should have been Grassington, Yorkshire.
2—4.	G. bidorsalis, P. *Mus. G.*	43—47.	G. mixolobus, P. *Ditto.* The specimens 45 and 47, differ from the others, especially in the elongation of one of the lateral sinuses.
5, 6.	G. platylobus, P. *Ditto*		
7—9.	G. stenolobus, P. *Ditto.*		
10—12.	G. nitidus, P. *Ditto.*		
13—18	G. Gibsoni, P. *Mus. Gibson.*		
19—21.	G. vesica, P. *Mus. G., P.*	48—50.	G. serpentinus, P. *Mus. G.*
22, 23.	G. calyx, P. *Mus. G., Gibson, P.*	51—55.	G. spirorbis, G. *Ditto.*
24—26.	G. mutabilis, P. *Mus. G.*	56—58.	G. rotiformis, P. *Mus. G., P.*
27—31.	G. Gilbertsoni, P. *Ditto.*	59, 60.	G. vittiger, P. *Mus G.*
32—35.	G. Looneyi, P. *Mus. Looney, G.*	61, 62.	G. intercostalis, P. *Ditto.*
36—38.	G. paucilobus, *Mus. G.*	63, 64.	G. carina, P. *Ditto.*
39.	G. Henslowi, S. *Woodwardian Museum.*	65—68.	G. evolutus, P. *Mus. Y. P. S.*

Plate XXI.—Orthoceras, page 237, *&c.*

1.	Orthoceras cinctum, S. *Mus.G.,Moore,P.*	8.	Orthoceras laterale, S. *Mus.G.,P.,Y.P.S.*
2.	O. unguis, P. *Mus. G.*	9, 10.	O. annulare, S. *Mus. G., Moore, Y.P.S.,P.*
3.	O. giganteum, S. *Mus. G., Y. P. S., &c.*	11.	O. reticulatum, P. *Mus. G.*
4.	O. angulare, P. *Mus. G., Gibson.*	12.	O. dentaloideum, P. *Ditto.*
5.	O. Steinhaueri, S. *Mus. G.*	13.	Part of Naut. cyclostomus? P. *Ditto.*
6.	O. Gesneri, M. *Mus. G., P., Y. P. S.*	14, 15.	Orthoc. pyriforme, S. *Mus. G., P.*
7.	O. inequiseptum, P. *Mus. G.*	16.	O. rugosum, Flem. *Mus. Y. P. S.*

Plate XXII.—Trilobites, &c., &c., page 239, *&c.*

1, 2.	Asaphus? quadrilimbus, P. *Mus. G.*	21, 22.	Claw of Crustaceous animal, *Mus. Y.P.S.*
3—6.	A. obsoletus, P. *Mus. G., P.*	23, 24.	Cypridiform shell, *Mus. G.*
7.	A. granuliferus, P. *Mus. P.,G., Portlock.*	25.	Agnostus? radialis, P. *Ditto.*
8—10.	A. seminiferus, P. *Mus. G.*	26.	Nautilus cyclostomus, P. *Mus. Gibson.*
11.	A. gemmuliferus, P. *Mus. G., P.*	27, 29.	N. tuberculatus, P. *Mus. P., Gibson.*
12, 13.	A. truncatulus, P. *Mus. Lord Cole.*	30.	N. costalis, P. *Mus. P.*
14, 15.	A. raniceps, P. *Mus. G.*	31, 32.	N. sulcatus, S. *Ditto.*
16—20.	A. globiceps, P. *Mus. R. Hutton, and Dr. Greene of Dublin.*	33, 34.	N. tetragonus, P. *Ditto.*
		35, 36.	N. oxystomus, P. *Ditto.*

Plate XXIII.—Diagrams.

These are described in the letter-press at the pages indicated.

Concerning No. 5, it may be necessary to observe that the sloping line marks the plane of a fault inclined at a small angle to the horizon, while the beds which are shifted by it dip steeply in the same direction. If we suppose these beds turned again nearly level (let the book be turned round 90°.) the fault will then be found to follow the ordinary laws of displacement (page 118.) This is the only case I have ever seen of an uplifted mass of previously dislocated strata, (producing an apparently horizontal fault.) In No. 6, the dark part is the vein; the shaded parts on each side the altered rock. In Nos. 9, 10, the dark parts are chiefly shale, the white parts limestone, the obliquely shaded parts coarse gritstone.

Plate XXIV.—Sections and Diagrams.

The three long Sections are sufficiently intelligible, without farther remark, than that they are drawn to a scale of 3000 feet elevation in one inch: the dark part (in No. 1,) is the coal formation: over it is a small extent of new red sandstone and magnesian conglomerate; the dotted part millstone grit series, (the strongest dotting shews particular grit rocks); the white parts are limestone; the shaded parts shale and gritstone;—the vertical lines mark the grauwacke basis of the Penine region. In tracing the edges of the different limestones of the Yoredale series round the hill sides, the geologist is greatly assisted by a peculiarity of the drainage, arising from the contrast between the pervious limestone and the watertight grits and shales. It is almost an invariable character of these limestones on sloping ground, to be marked along, or rather a little above, their surfaces by a series of round hollows, or deep pits, which gather the water from the shaly surface, and suffer it to pass downward and to issue at some lower point in a spring. In all the northern and western dales of Yorkshire the five principal Yoredale limestones, and sometimes also the thinner beds between them, are marked on the surface by parallel ranges of such 'swallow holes,' and pits, often shewing the peculiar corrosion of acidulated water. The phenomenon is generally independent of disturbed stratification; and in fact is chiefly the result of atmospheric action and rain, on the jointed calcareous rocks. The diagrams Nos. 14 to 19, are sufficiently explained in the text. 20. Gordale is in lower scar limestone. 21. Outline of Ingleborough: the top is lower millstone grit: the prominent ledge below is main limestone, the next prominent ledge is a thick sandstone, and from this to the limestone floor, which is the basis of the mountain, the steep slopes are formed principally of shale (with thin limestones and gritstones.) 22. Part of Brimham rocks—the upper millstone grit. 23. In this sketch of part of Craven the smooth outlines and insular hills are formed of shale, and thin limestones; the dark rougher ground is millstone grit. 24. Must be studied by referring to the text of Chap. vi. p. 176. It is principally intended to call attention to the important fact that the local origin of the limestones is different from that of the sandstones and shales; the former arriving at a maximum thickness in the S. E.—the latter in the N. W.

Plate XXV.—The Geological Map.

This map contains nothing conjectural; it is wholly drawn from personal observation, except a small part of the range of magnesian limestone near Markington, which I have taken from Professor Sedgwick, (Geological Transactions) and the outline of the small coalfield of Ingleton, which was given me by Mr. Hodgson. Almost every part is minutely correct; a small portion about the head of Lunedale, and the new red sandstone and magnesian limestone tracts near Ingleton and Kirby Stephen, excepted, (where it is almost impossible for accuracy to be obtained.)

It was found impracticable to transfer to this map the minute delineation of the Yoredale limestones which I have performed on the large County Survey, for almost every branch stream of Ribblesdale, Airedale, Wharfedale, Yoredale, Swaledale, Edendale, Garsdale, Dentdale, and part of Teesdale, as well as for the whole Penine chain. In the low Craven country, almost all the narrow limestone ridges mentioned in the text belong to the Yoredale series, and for this reason are not specially marked. The breadth assigned to the lower scar limestone in the anticlinal elevations of Skipton and Lothersdale is beyond the truth, but at those points the upper limestones (which belong to the Yoredale series) are very closely connected with the lower masses. It must be remembered that the shading adopted for millstone grit series includes all the strata between the Yorkshire coal basin and the top of the main limestone; some thin limestones occur in this mass.

The superficial extent assigned to the Whin sill is very nearly correct; a part of the range on the south side of the Tees assumes somewhat of the aspect of a great dyke; and if, as I believe, the eruptions of basalt have been often repeated in this valley, we may hereafter discover the means of distinguishing the products of different æras.

The general absence of igneous rocks on the line of the Penine and Craven faults, at all points (except Ingleton) south of the Cross fell region, is a remarkable circumstance, which ought not to be forgotten in reasoning on the agencies concerned in producing such disturbances of the strata.

Along the line of these faults the usual deposits of calcareous tufa are abundant, particularly on the range of the Craven fault: but no sulphureous, remarkably chalybeate, or saline springs, occur any where in special connexion with such lines of disruption except about Harrogate. Here, where two lines of fault, E. and W. and nearly N., coincide, chalybeate and sulphur springs abound. Farther north, at Aldfield near Ripon, on the line of the axis of dislocation which passes E. and W. through Greenhow and Brimham, the phenomena of sulphur wells are repeated; and a third case occurs in the lower part of Teesdale, at Middleton One Row, on the subterranean line of the southern boundary of the Durham coalfield, which is also an axis of disturbed strata. It is probable that in each of these instances the springs derive their sulphureous impregnation from some peculiar action on the shales of the millstone grit series—some of which on a sunny day, by merely rubbing the earth with the hand, will disclose the smell of disengaged sulphur.

The basaltic dykes noticed p. p. 81, 82, Fryerfold vein in Swaledale and several other veins, some anticlinal axes, faults, and remarkable dips, are represented by distinct characters.

It was found by trial better to engrave characters on the plate than trust to colour for distinguishing the groups. The selection of these characters is not arbitrary, but forms part of a system on which much attention has been bestowed, and of which I propose ere long to produce a complete specimen and full description, in a Map of the British Isles.

FINIS.

(Thomas Wilson and Sons, High-Ousegate, York.)

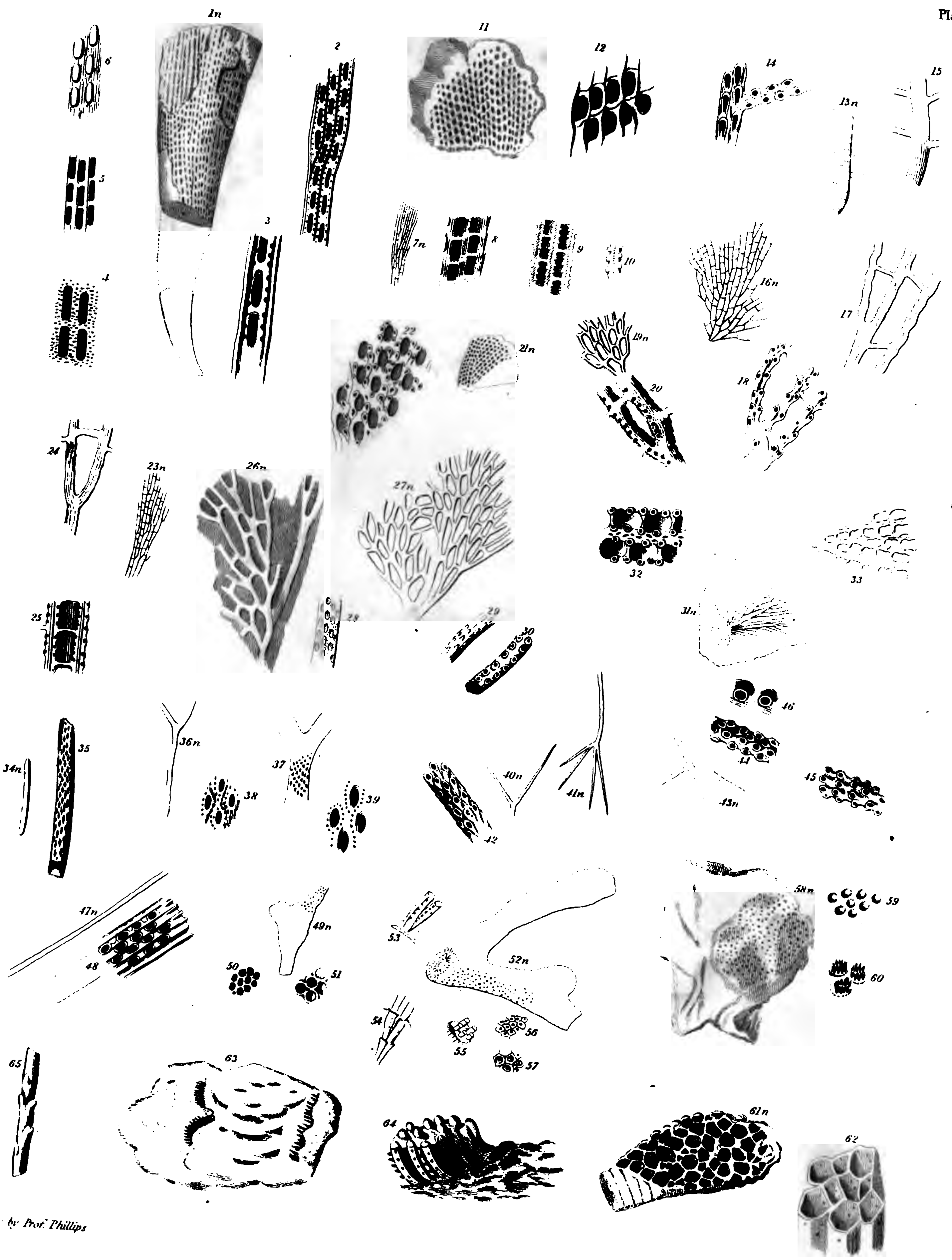
ERRATA OBSERVED.

Page 93 line	3 from bottom,	*for* black *read* block.
201	11 from top,	*for* 2, 9, *read* 29.
224	4 from bottom,	*for* 24, *read* 30.
235	9 from bottom,	*for* variabilis, *read* reticulatus.
237	1 from top,	*for* Bolland, *read* Grassington.
—	4 from top,	*add* 'slightly pointed.'

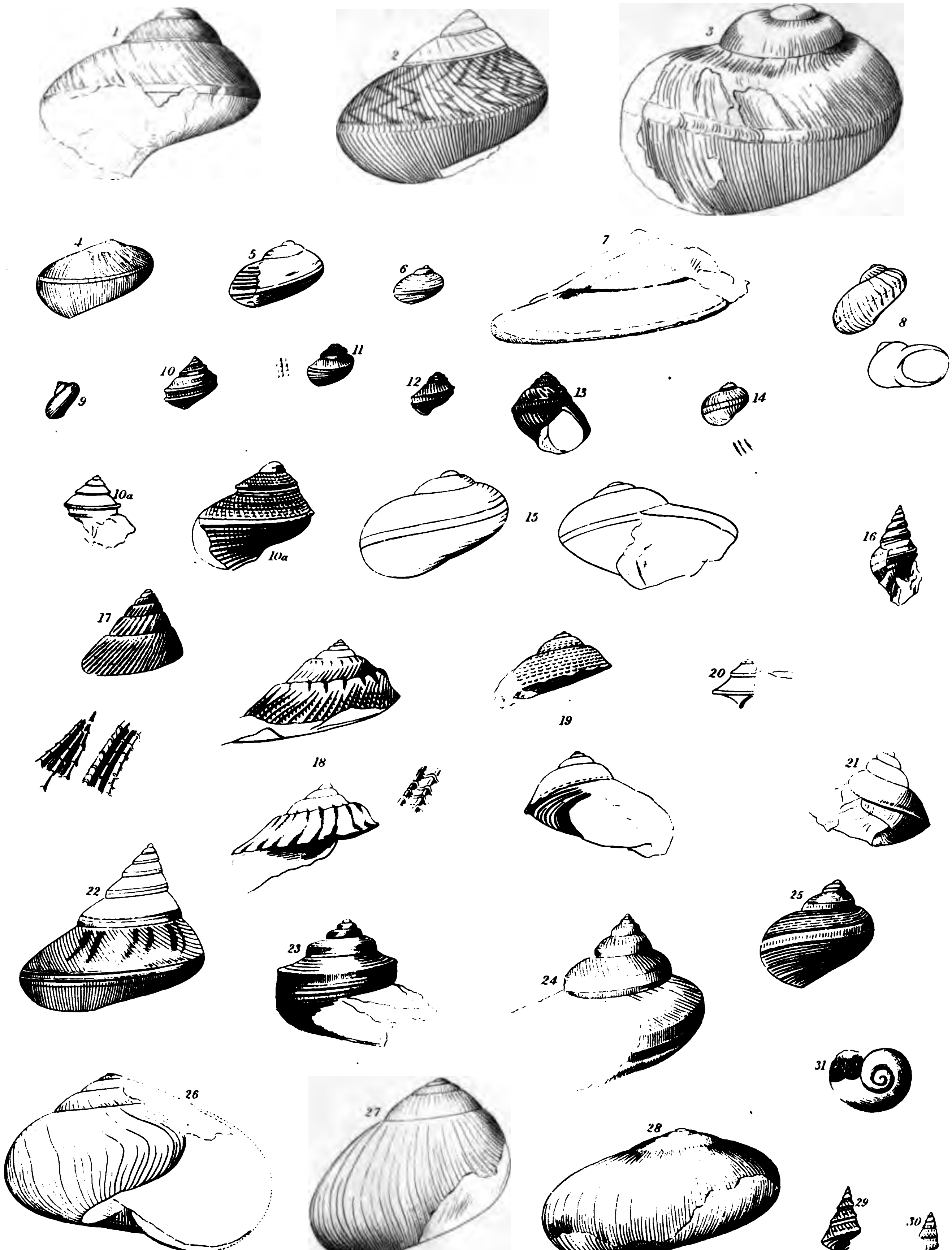
ADDITIONAL ERRATUM.

Page 253, line 21, *for* E. and W. *read* N.E. and S.W.

Pl. 8



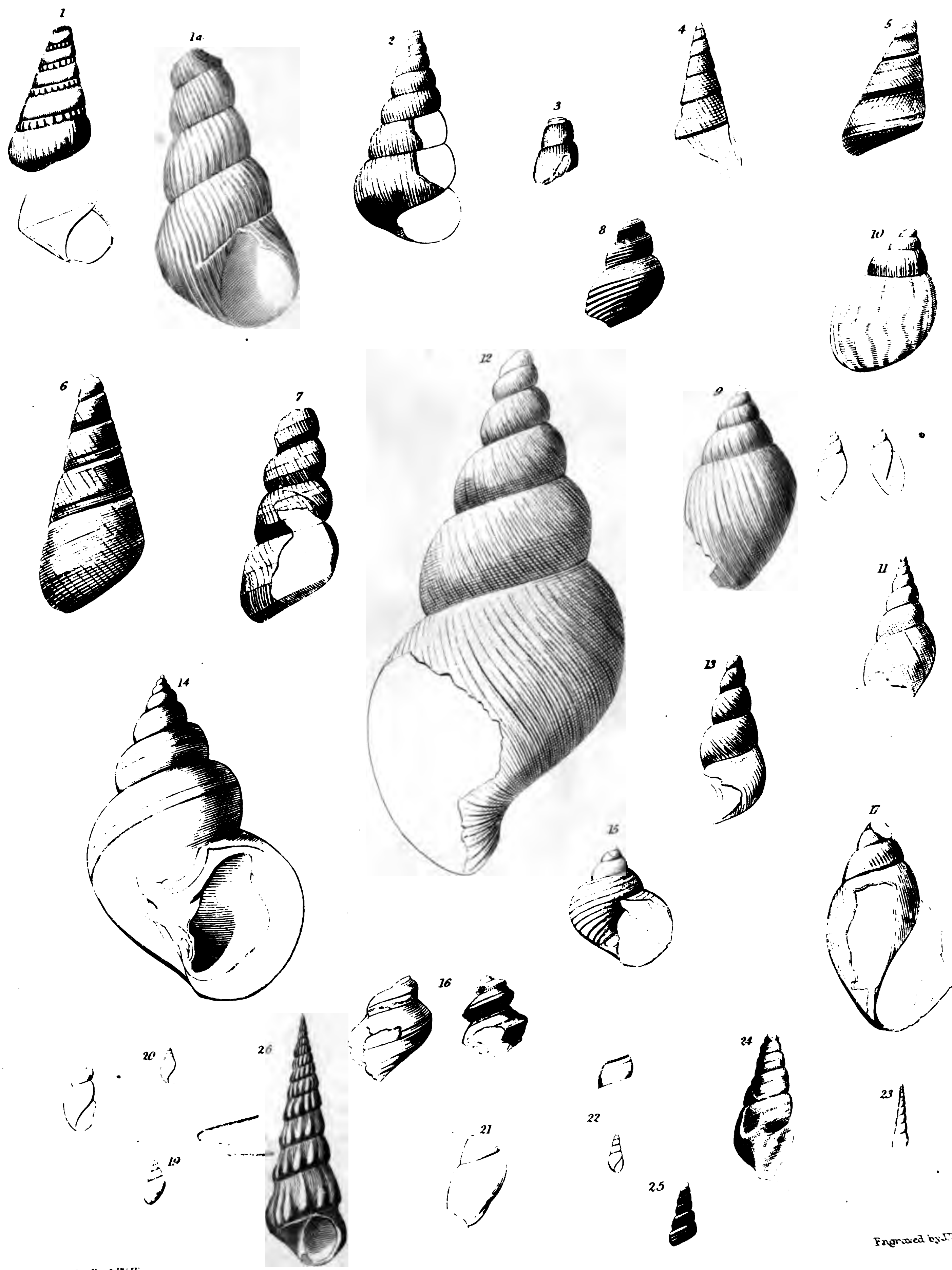
by Prof. Phillips



Drawn by Prof. Phillips.

Engraved by J.W. Lowry.

GASTEROPODA



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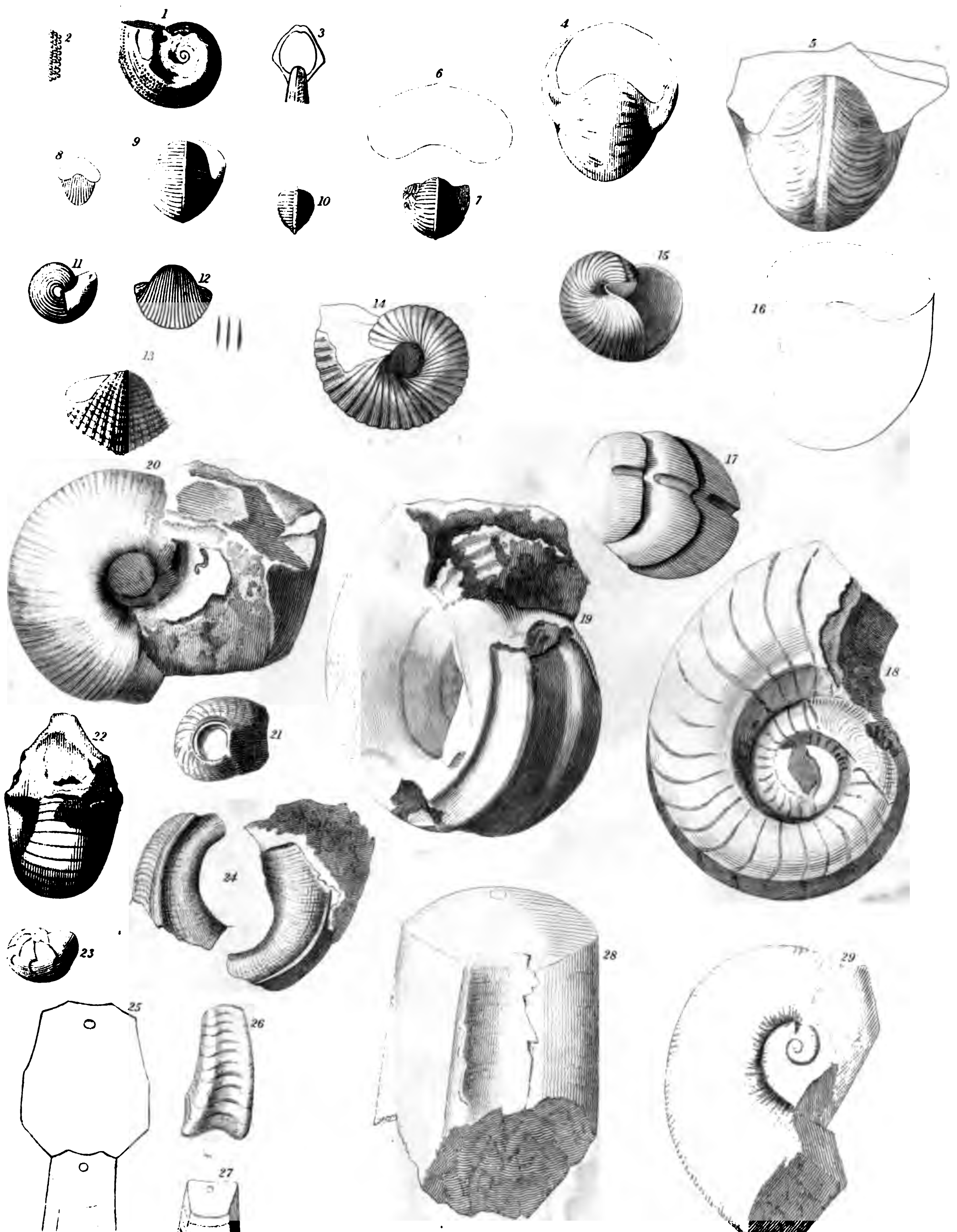
Engraved by J.&J.L.

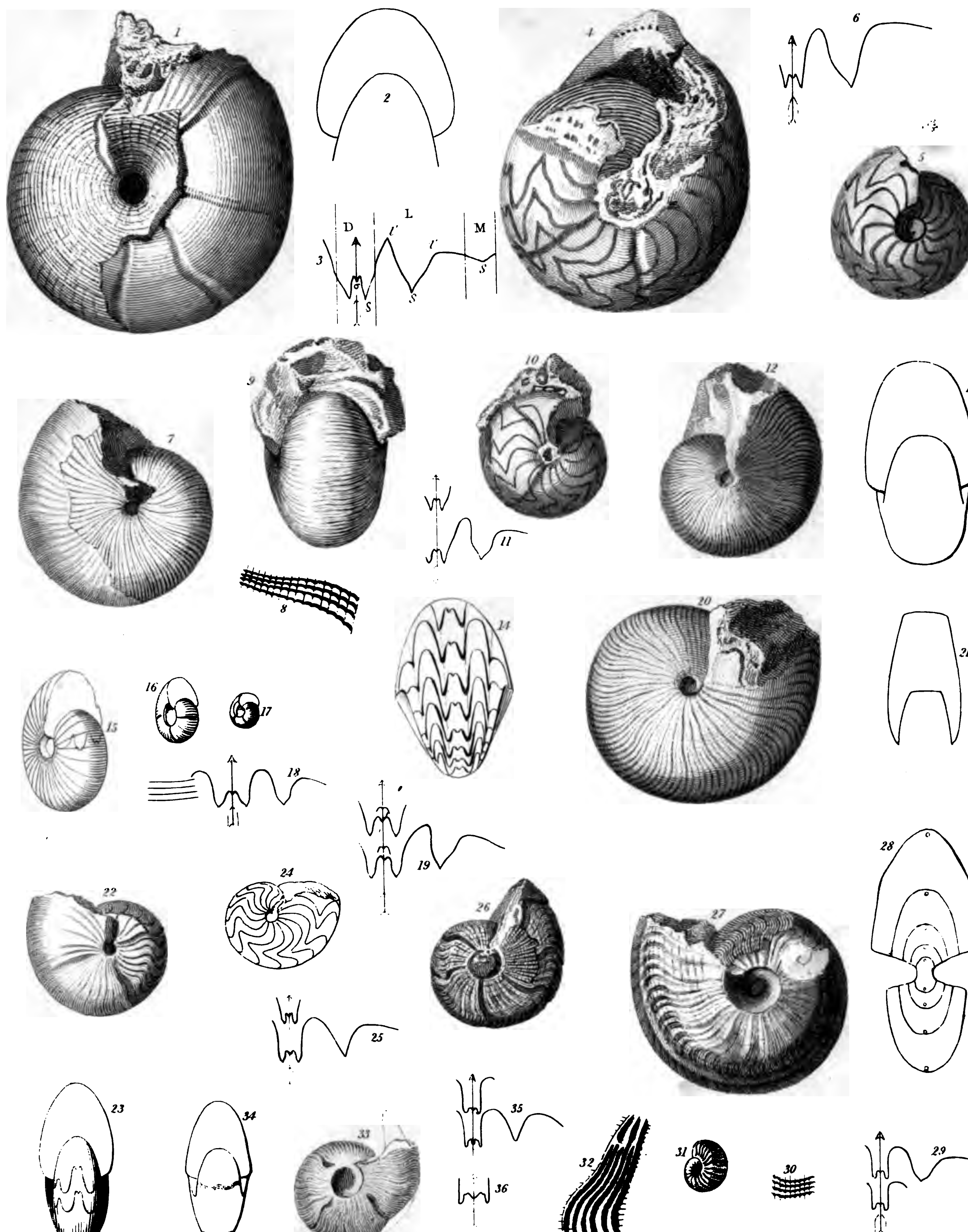


'rawn by Prof. Phillips.

Engraved by J. W. Lowry.

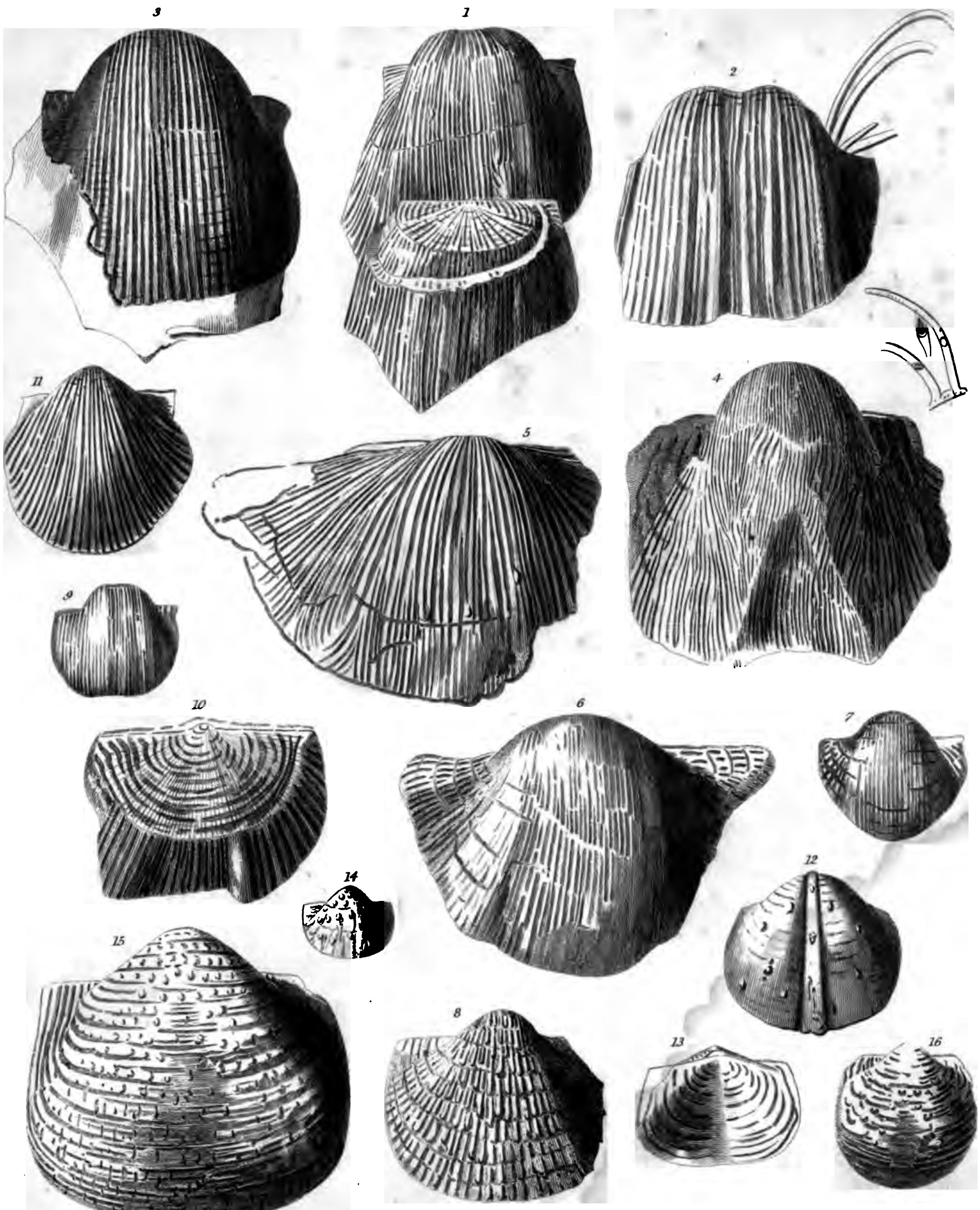
by Prof. Phillips

Engraved by J.W. Lowry



Drawn by Prof. Phillips. Engraved by J. W. Lowry

PRODUCTA



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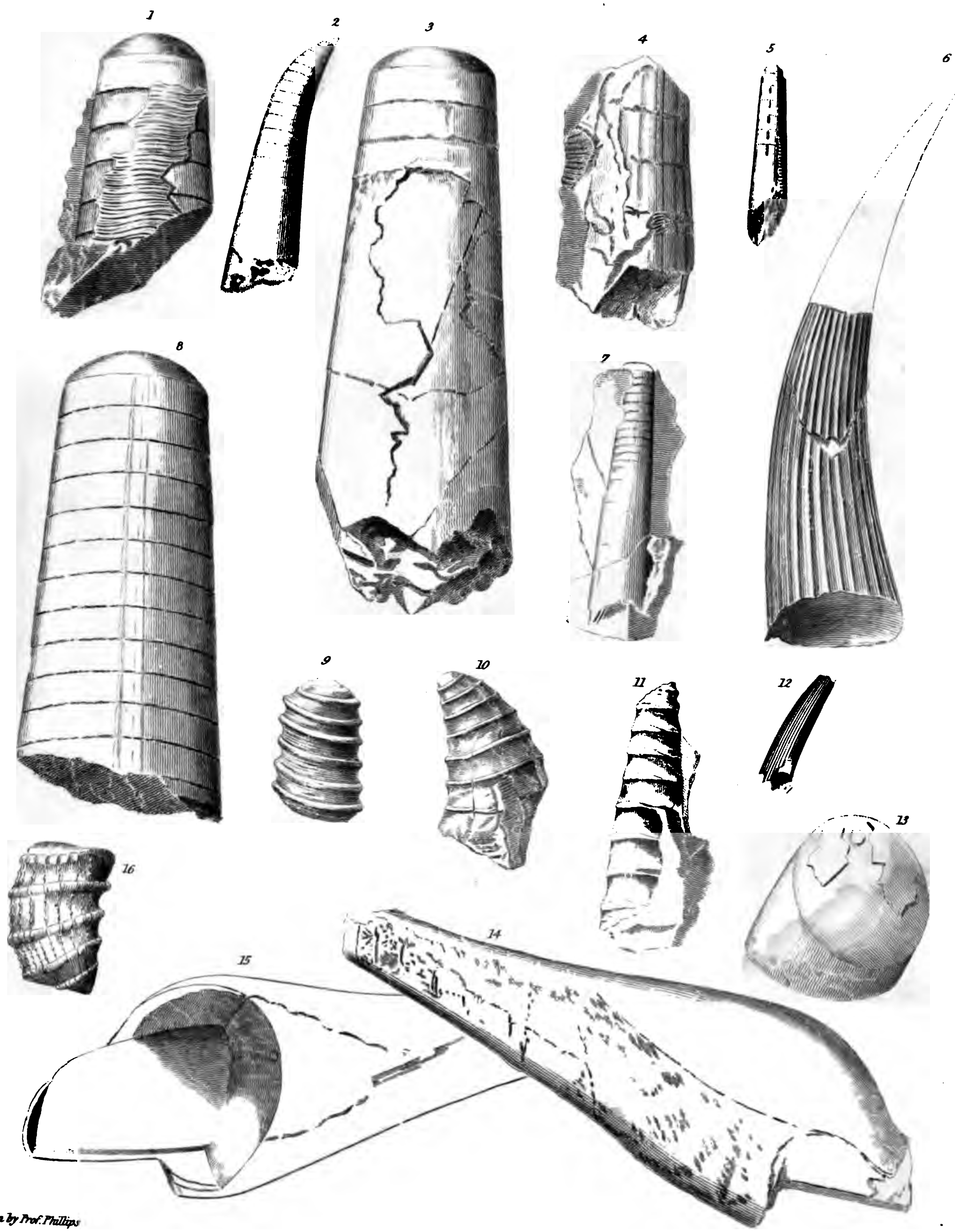
ORTHOCERAS



Drawn by Prof. Phillips

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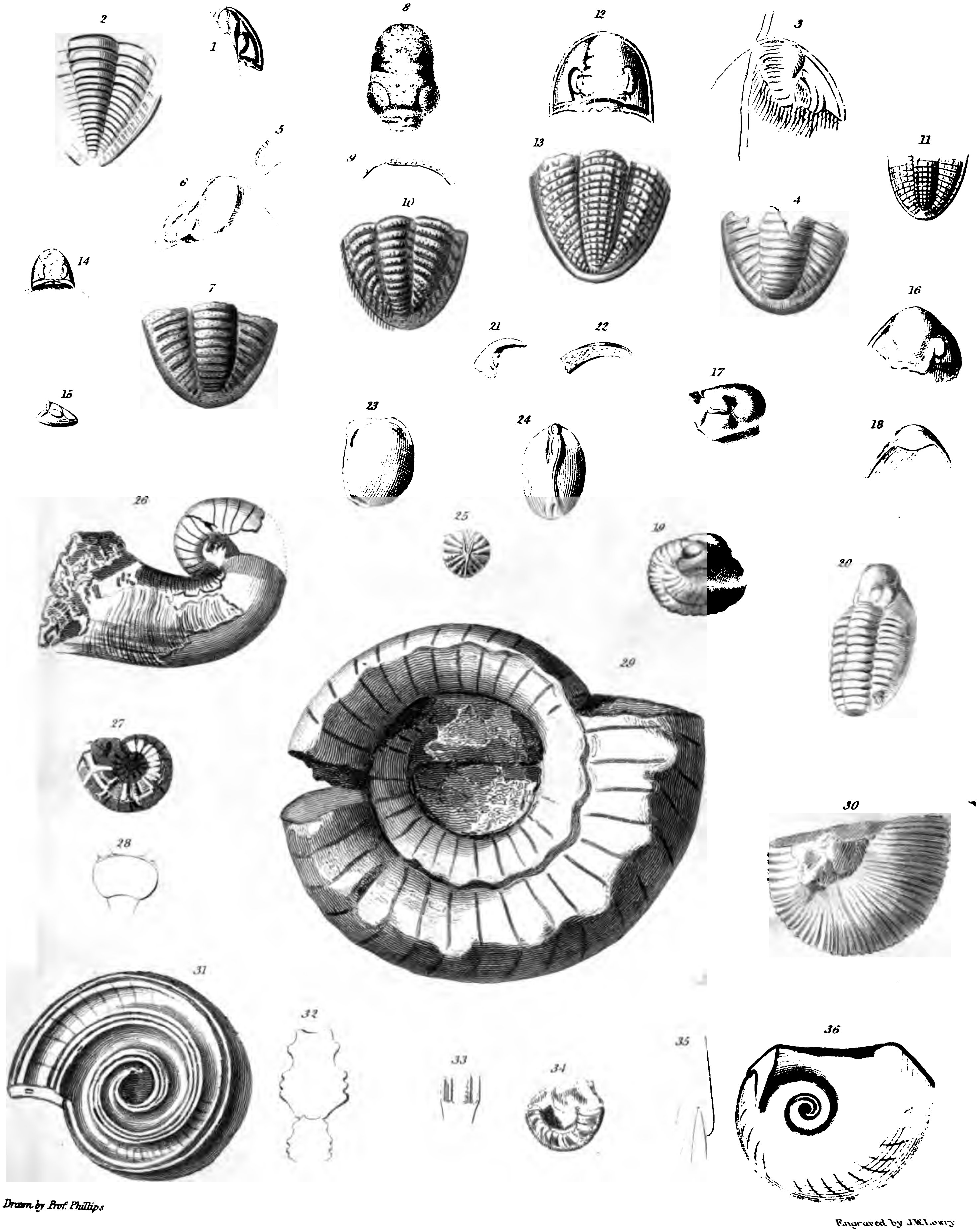
CRUSTACEA &c.



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DIAGRAMS.

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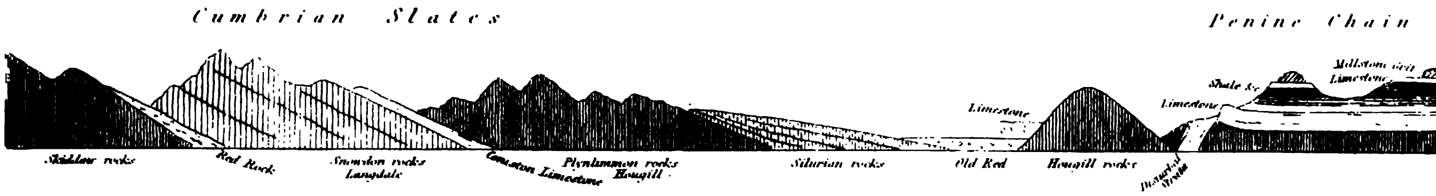

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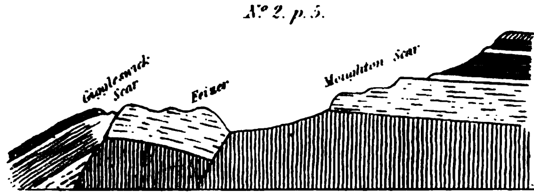

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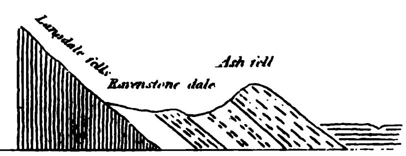

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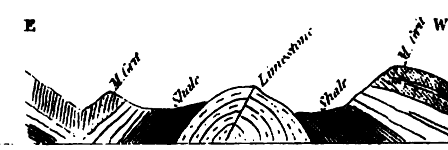

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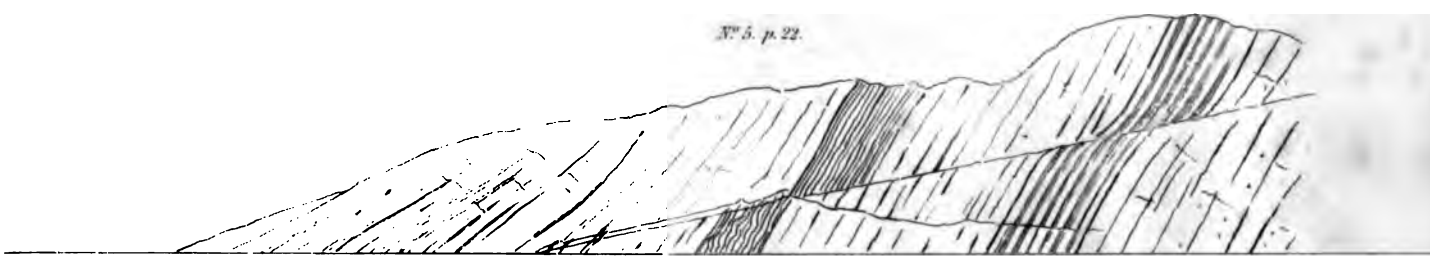

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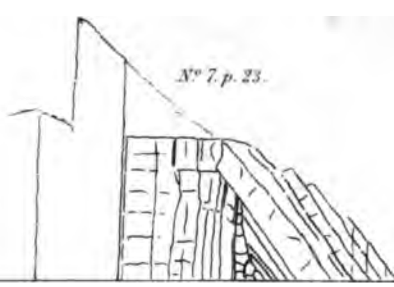

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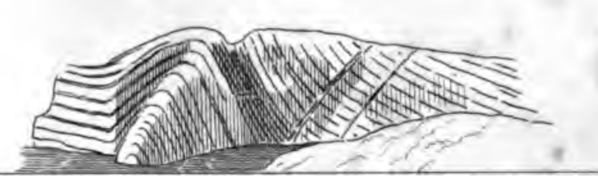

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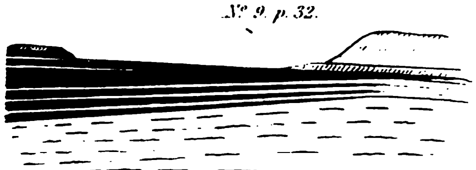

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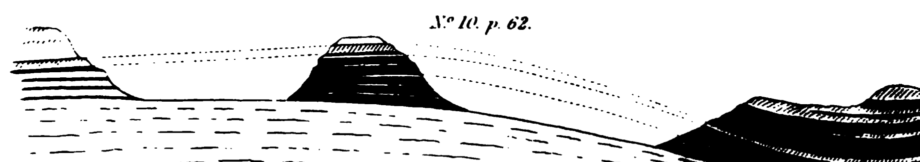


No 12 p 79 & 92.

High Force.

No 11. p.81

No 13. p.165.

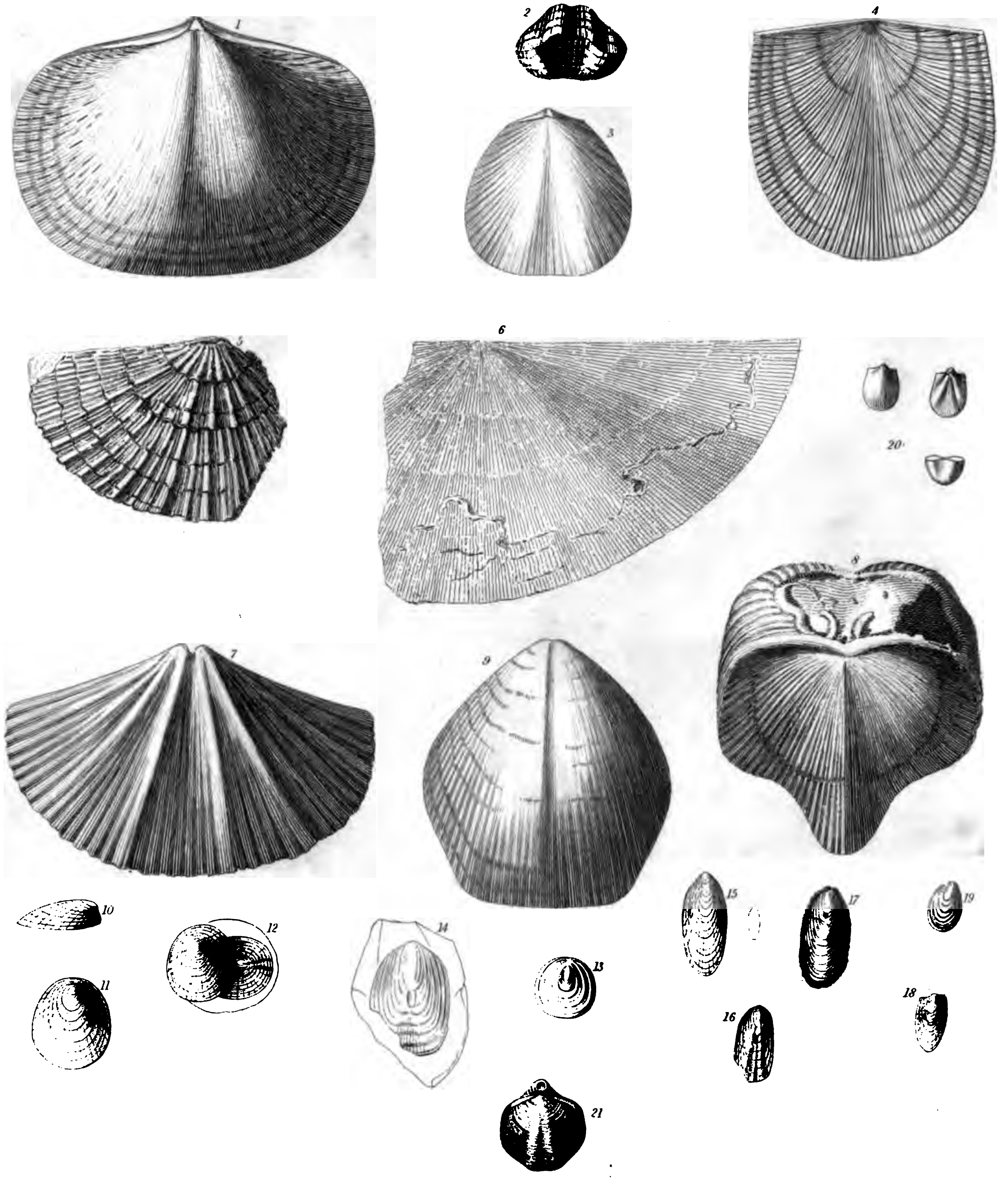
Thornton Force.

Drawn by Professor Phillips

Engraved by J.W.

BRACHIOPODA

Plate XI



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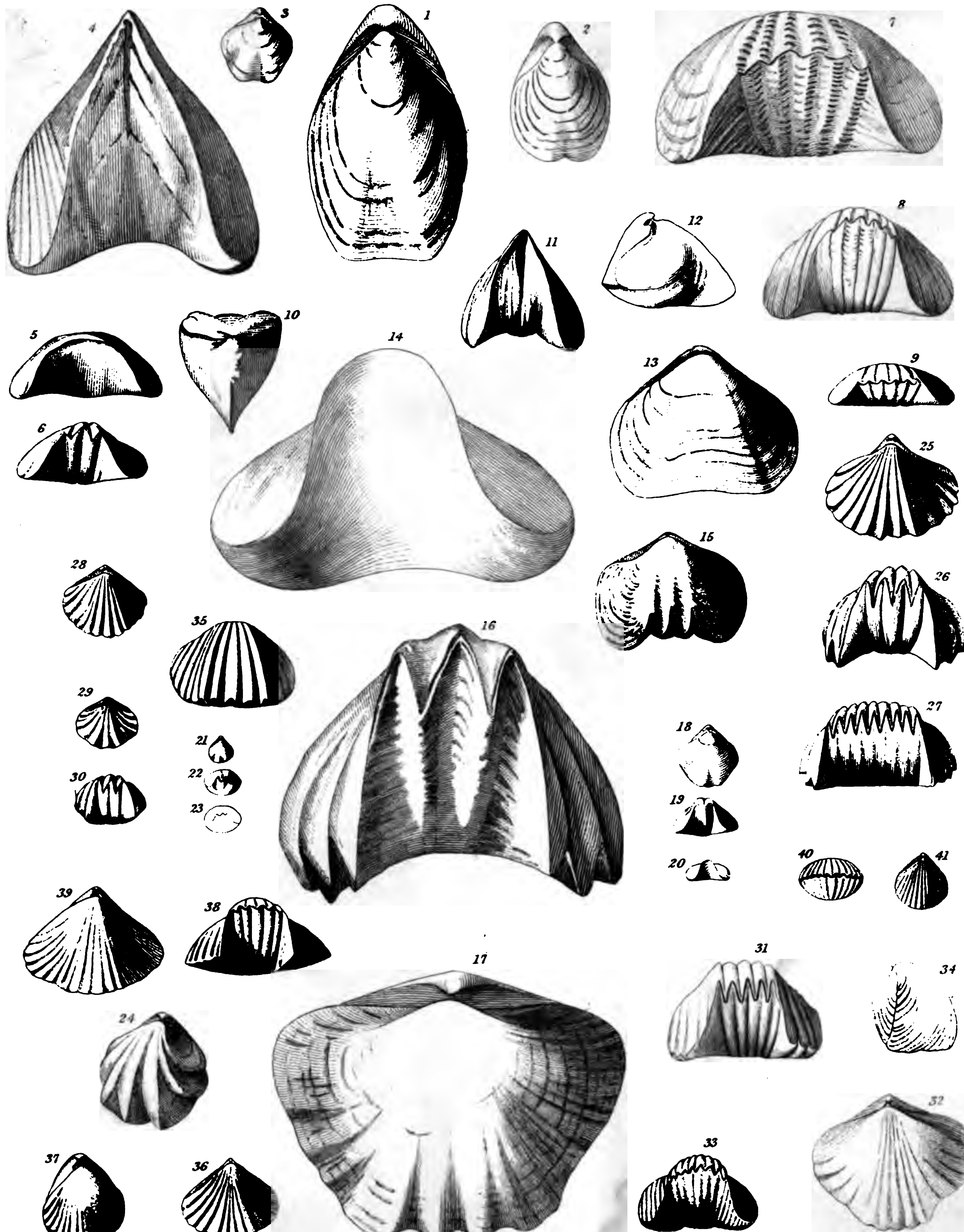
Engraved by J.W. Lowry.



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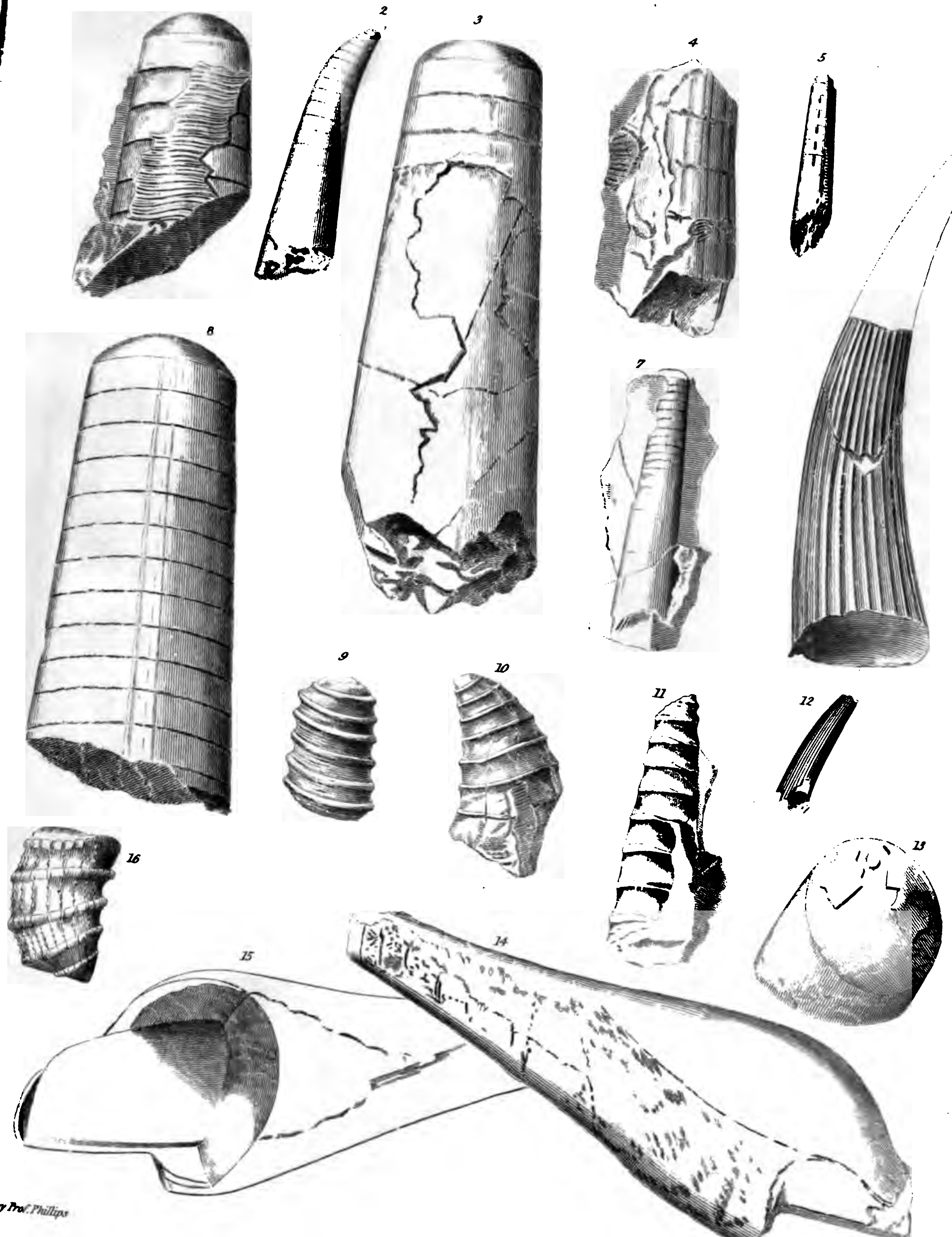
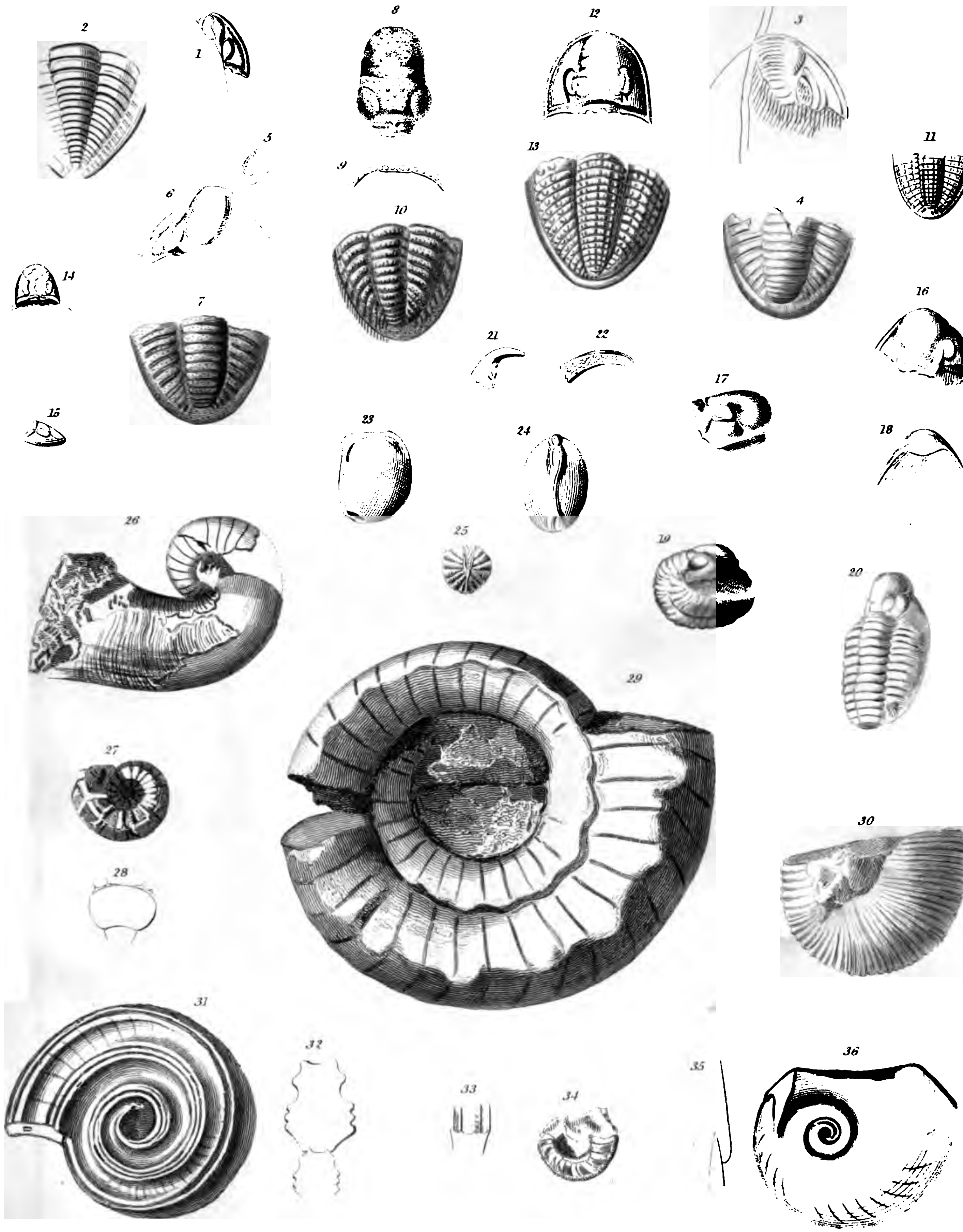
ORTHOCERAS



[…] by Prof. Phillips



Drawn by Prof. Phillips

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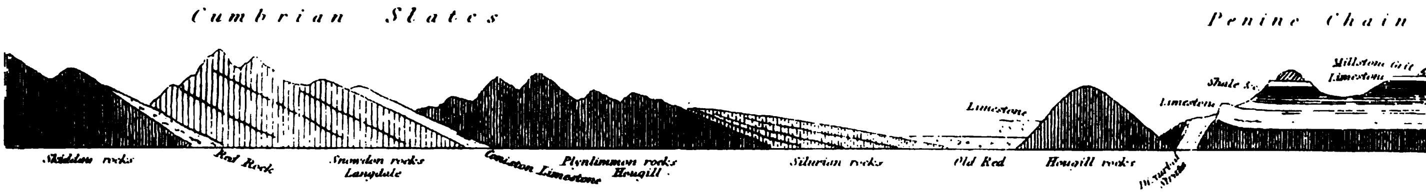

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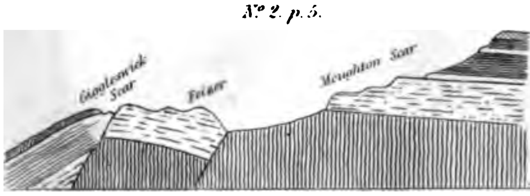

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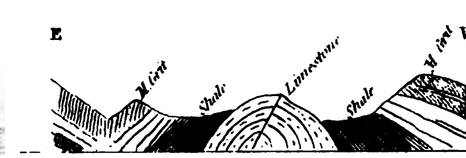

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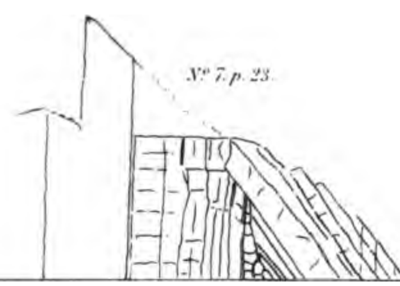

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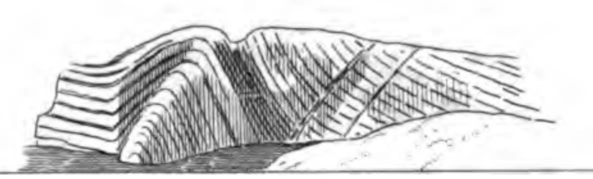

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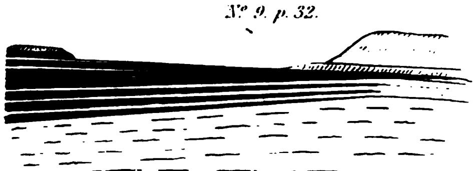

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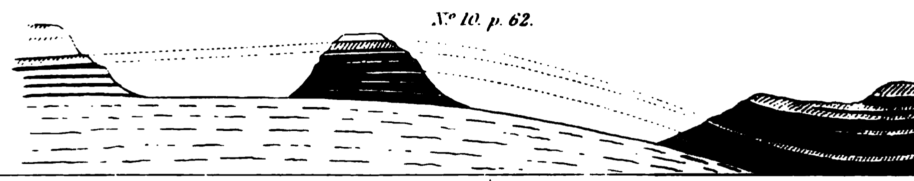


N.º 12. p. 79 & 92.

High Force

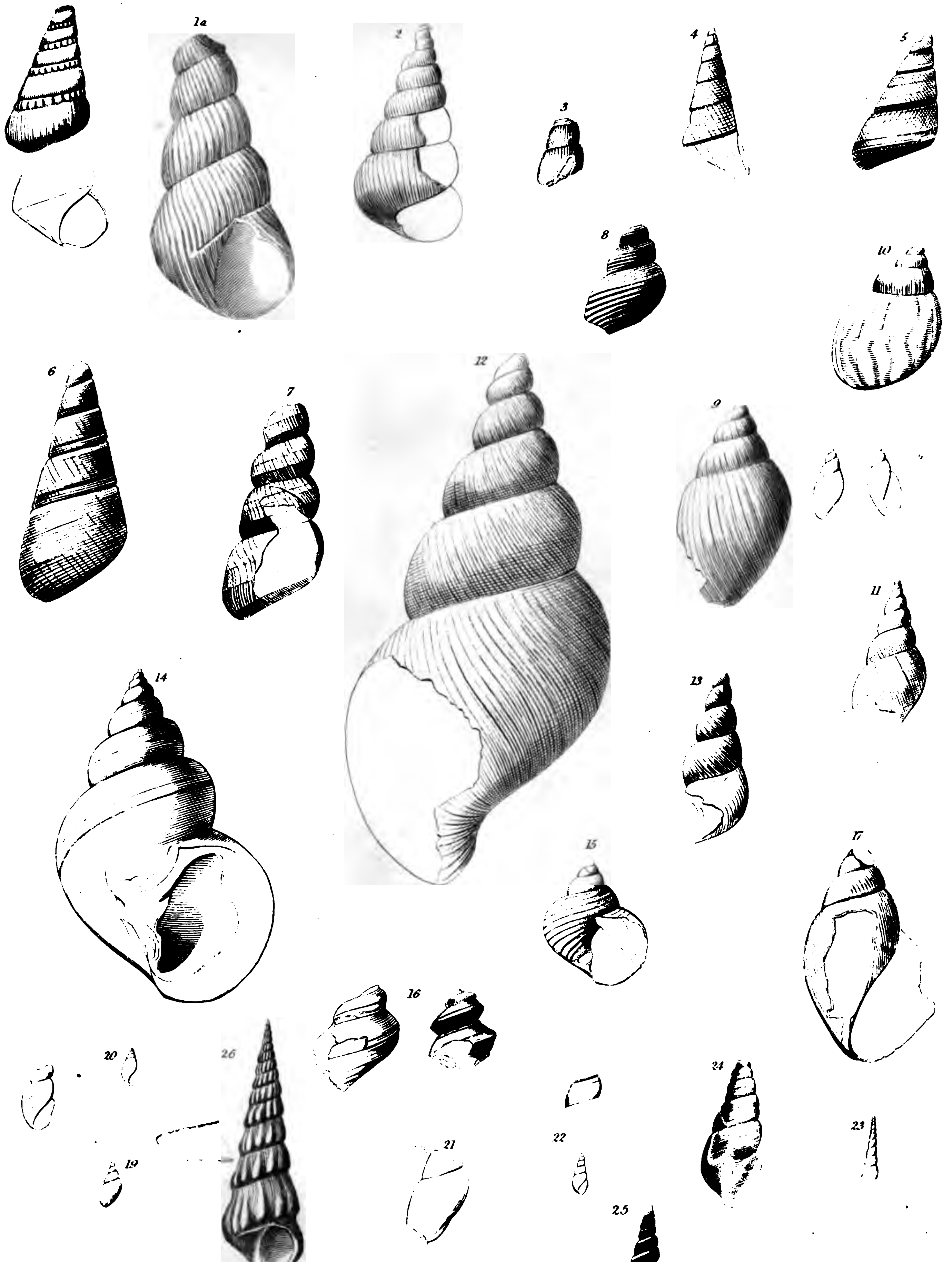
N.º 11. p. 81

N.º 13. p. 165

Thornton Force.

Drawn by Professor Phillips

Engraved by J.



Drawn by Prof. Phillips

Engraved by J. W. Lowry

CEPHALOPODA

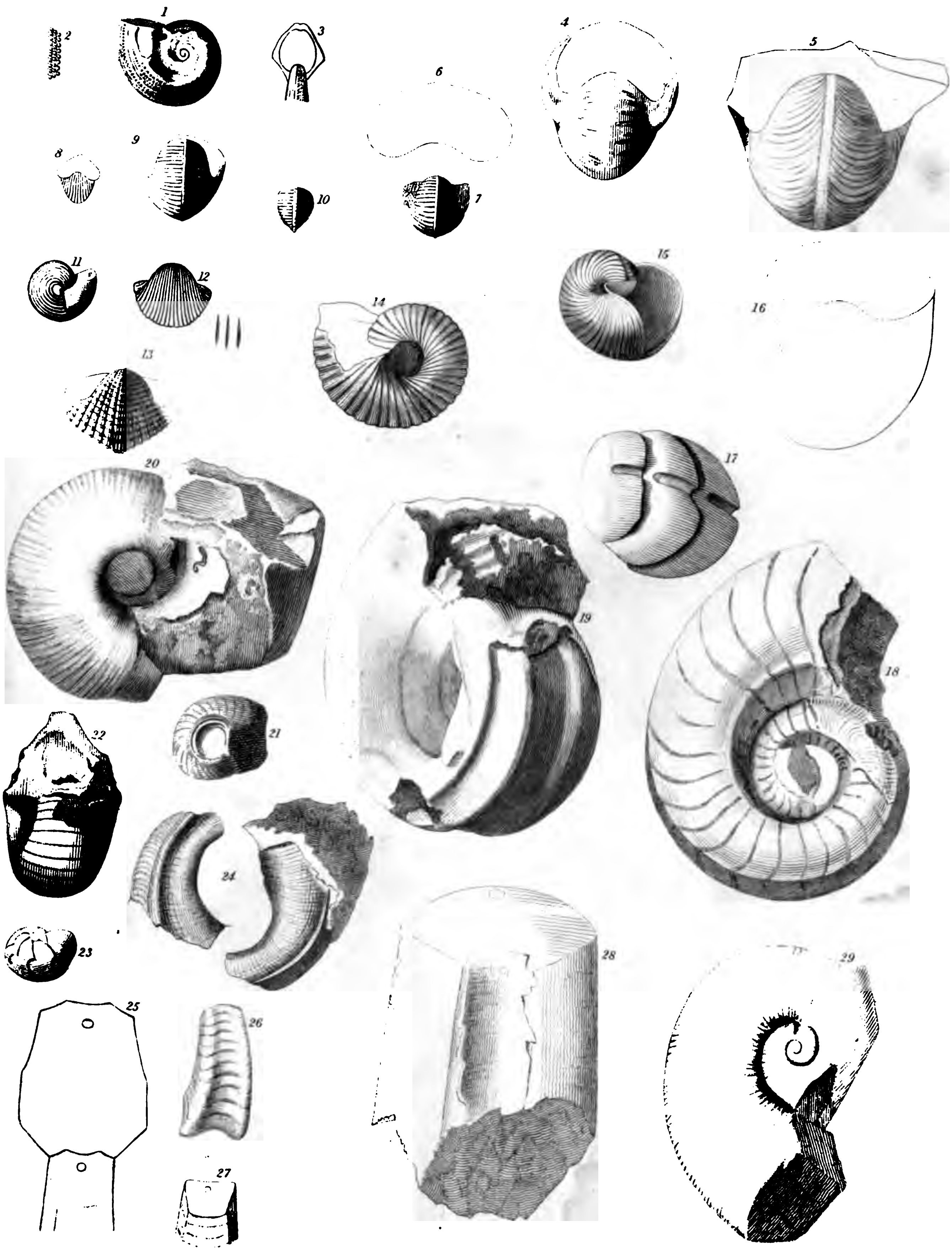


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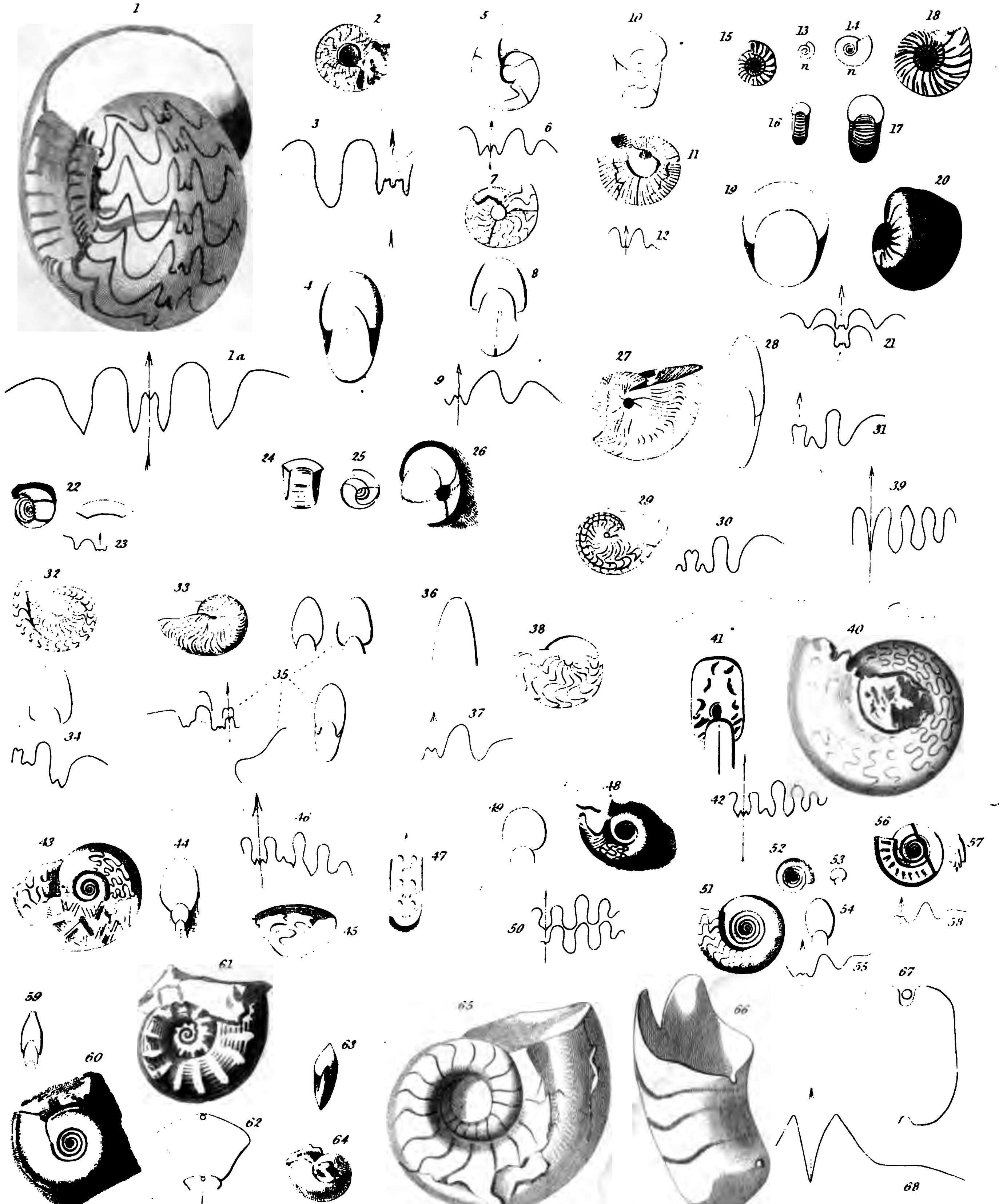
Plate XX.

GONIATITES



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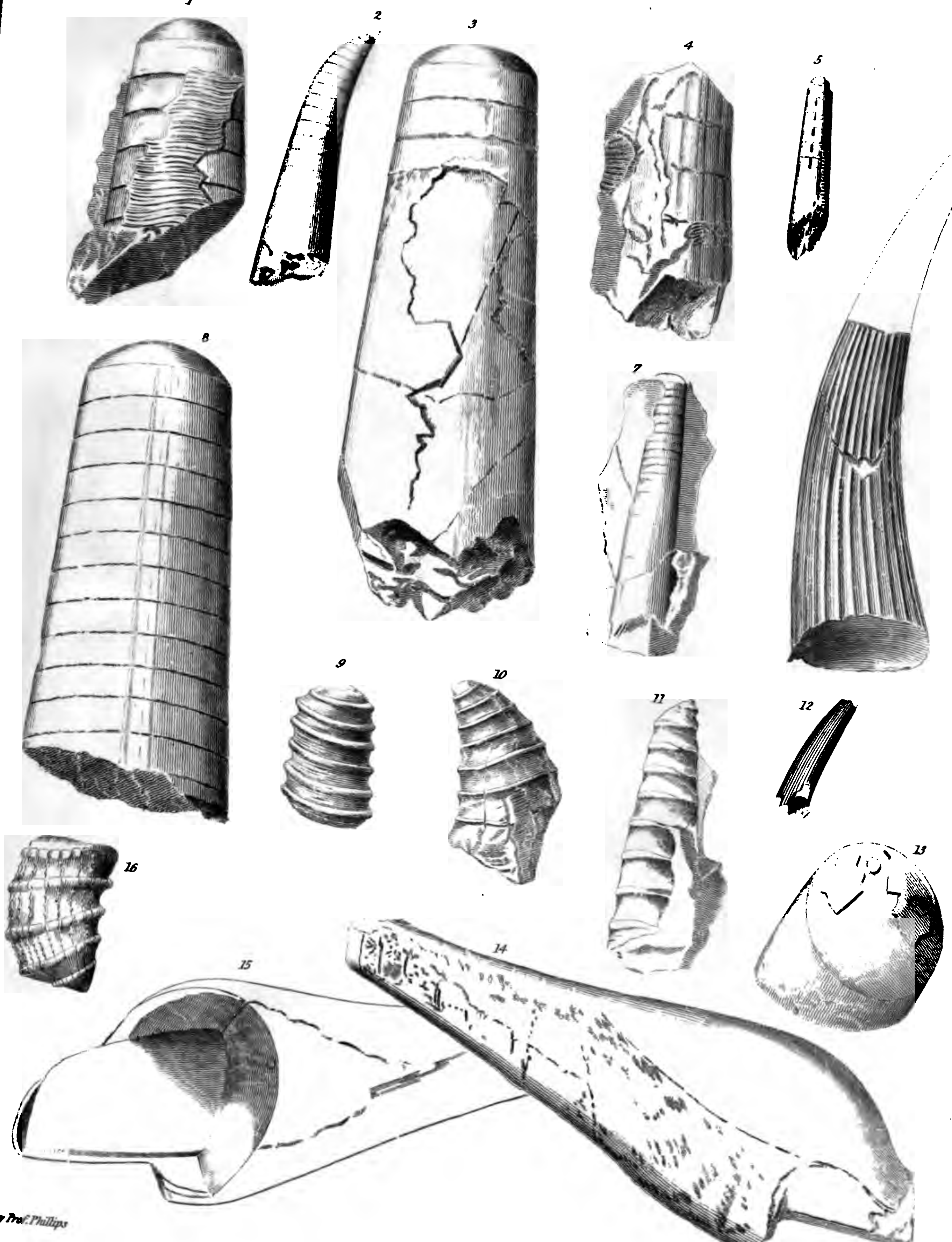
ORTHOCERAS



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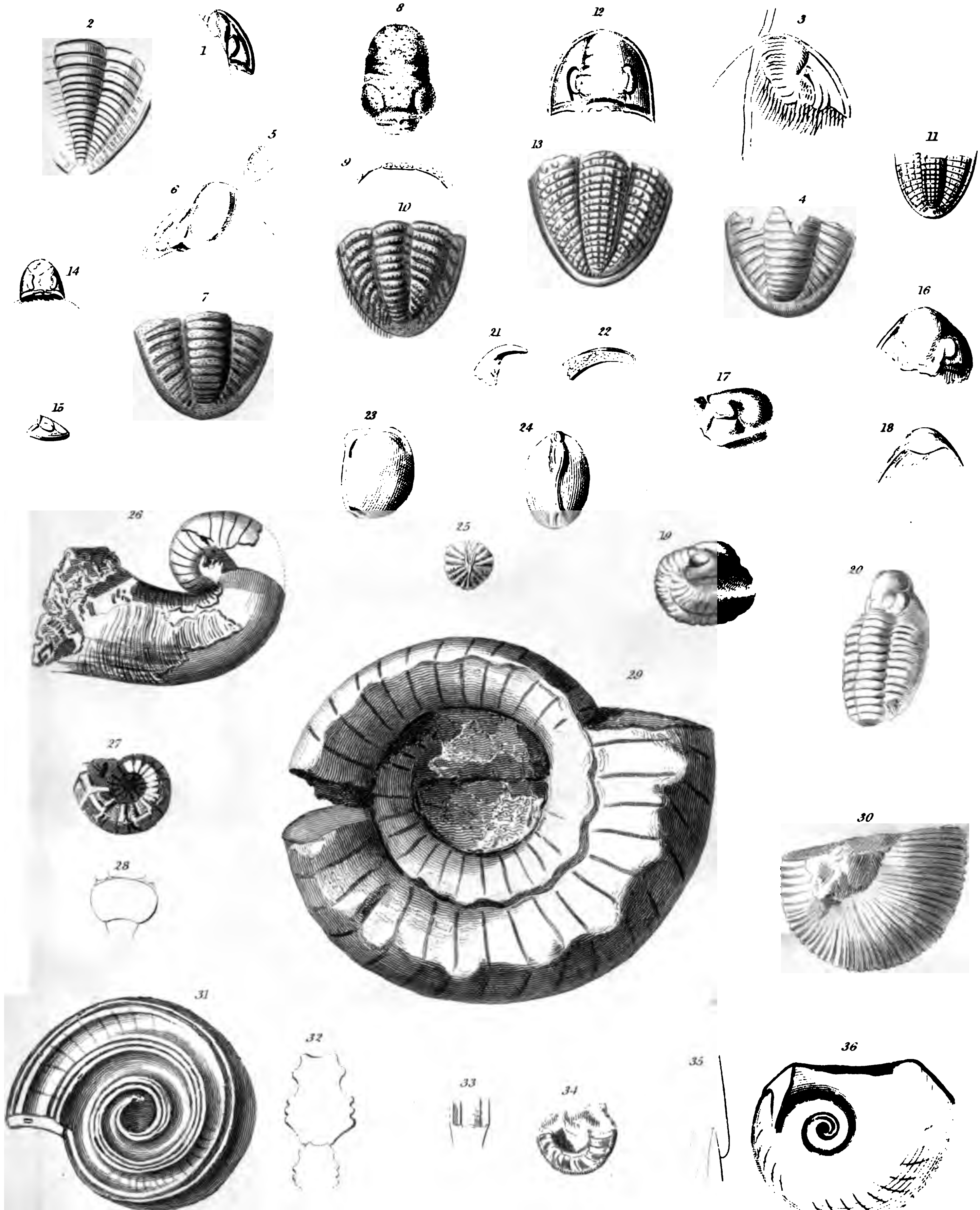

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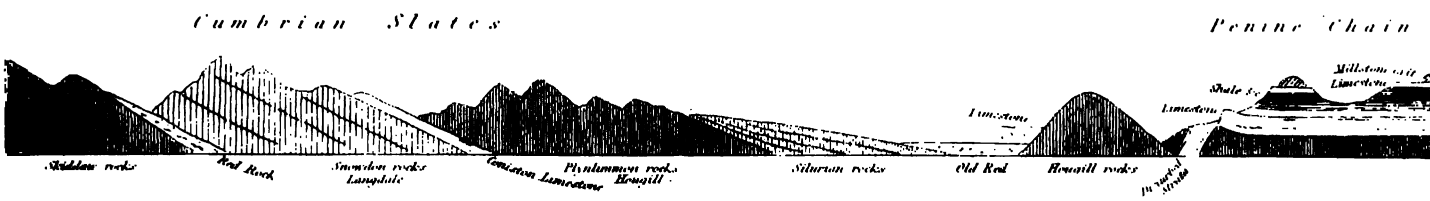

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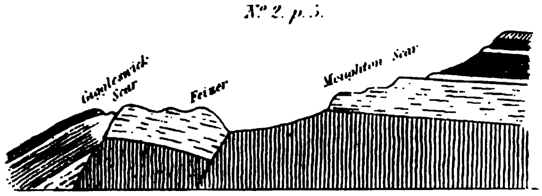

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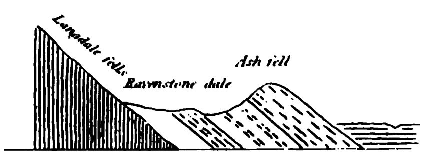

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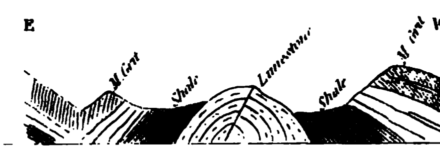

No 6. p 22

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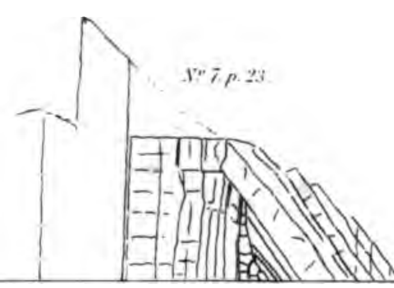

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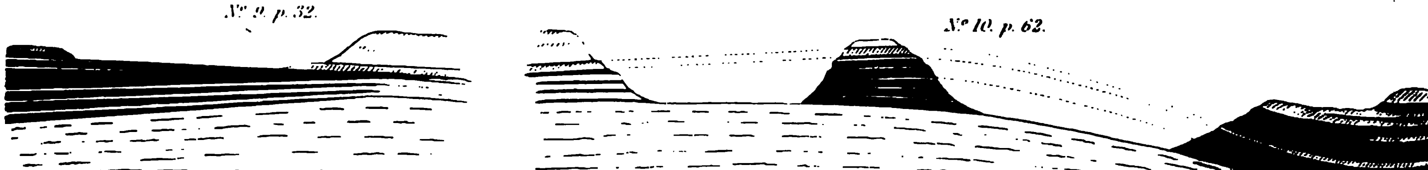


No 12. p. 79 & 92.

High Force.

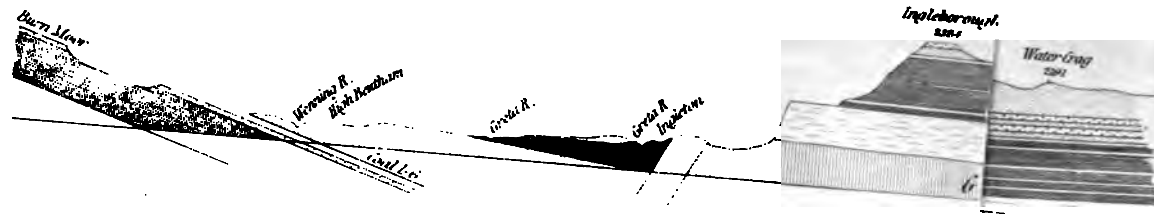
No 11. p. 81.

No 13. p. 165.

Thornton Force.

Drawn by Professor Phillips.

Engraved by



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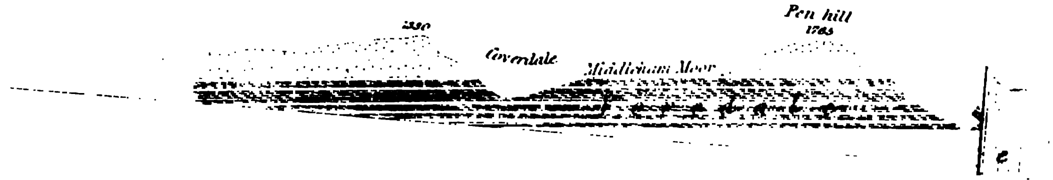
Level of Sea



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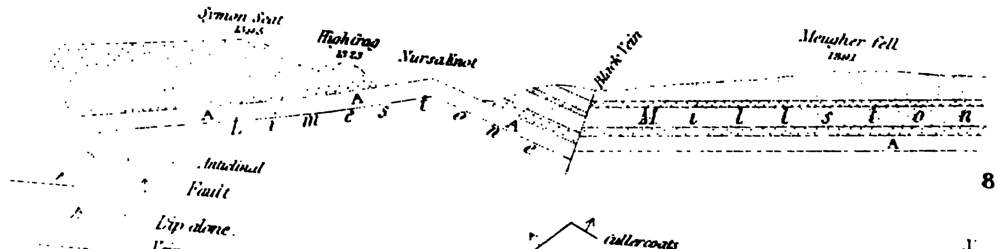

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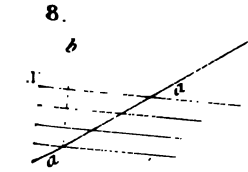

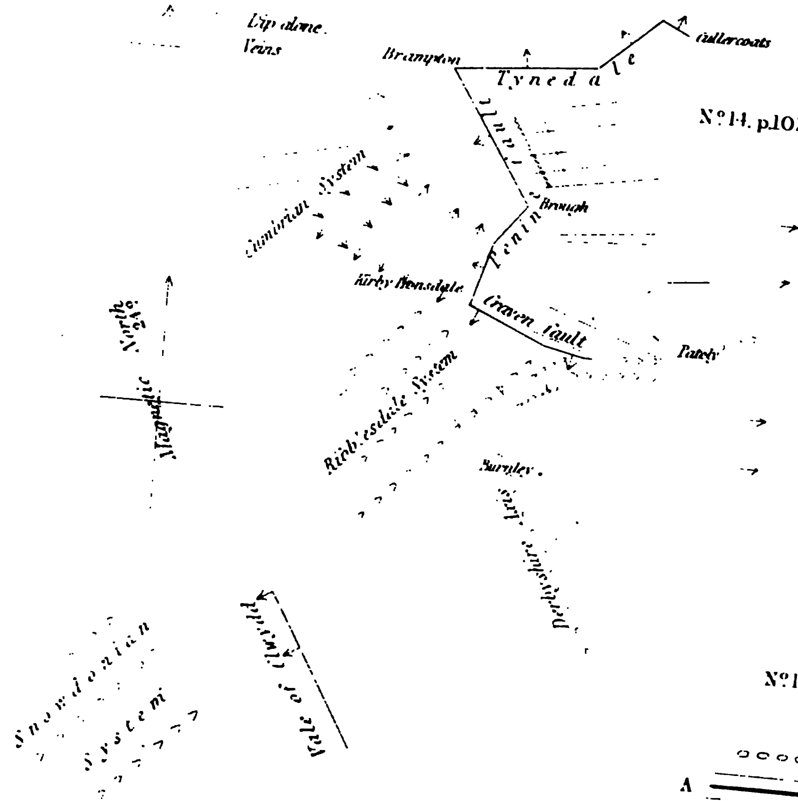

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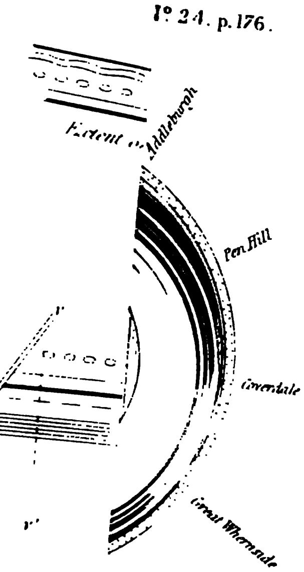
N°24. p.176.



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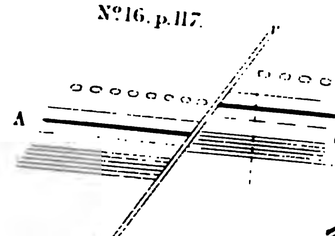

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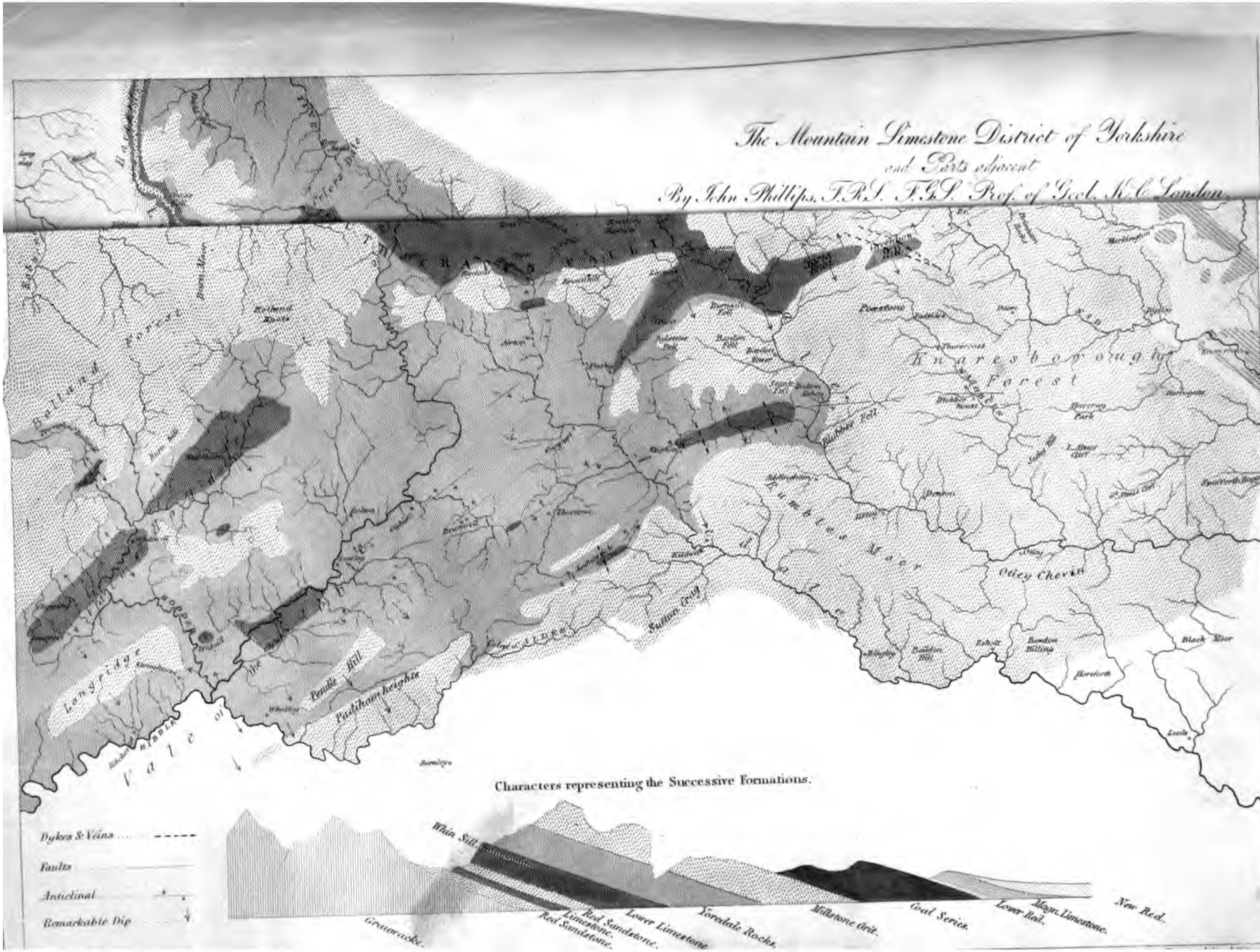
The Mountain Limestone District of Yorkshire
and Parts adjacent
By John Phillips, F.R.S. F.G.S. Prof. of Geol. K.C. London.
Knaresborough Forest
Rumbles Moor
Otley Chevin
Longridge
Pendle Hill
Padiham heights
Vale of
Black Moor
Characters representing the Successive Formations.
Dykes & Veins
Faults
Anticlinal
Remarkable Dip
Whin Sill
Grauwacke.
Red Sandstone.
Limestone.
Red Sandstone.
Lower Limestone
Yoredale Rocks.
Millstone Grit.
Coal Series.
Lower Red.
Magn. Limestone.
New Red.